

HOME INSULATION

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REPORT

BY THE

SUBCOMMITTEE ON OVERSIGHT AND  
INVESTIGATIONS

OF THE

COMMITTEE ON INTERSTATE AND  
FOREIGN COMMERCE

HOUSE OF REPRESENTATIVES

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## LETTER OF TRANSMITTAL

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HOUSE OF REPRESENTATIVES,  
SUBCOMMITTEE ON OVERSIGHT AND INVESTIGATIONS  
OF THE COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE,  
Washington, D.C., April 26, 1978.

HON. HARLEY O. STAGGERS,  
*Chairman, Committee on Interstate and Foreign Commerce, U.S. House  
of Representatives, Washington, D.C.*

DEAR MR. CHAIRMAN: The attached report of the Subcommittee on Oversight and Investigations on home insulation has been prepared in response to growing concern over the safety and quality of home insulation.

The report, based on three days of public hearings and 4 months of study, recommends that the Congress enact legislation requiring the Consumer Product Safety Commission to set certain safety standards for cellulose and fiberglass insulation.

A failure to set such standards could jeopardize the safety of millions of American homes.

Sincerely,

JOHN E. MOSS,  
*Chairman, Subcommittee on Oversight and Investigations.*



## HOME INSULATION

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### *Introduction and Summary*

The Administration has identified the insulation of 90 percent of existing homes in the United States as a major goal of its National Energy Plan. Spurred by hopes of a tax credit, spiraling energy costs, and the desire to do what is right, Americans are reinsulating their homes in record numbers. According to the Department of Energy, between 25-47 million homes will be reinsulated by the end of 1985.

If there are significant hazards associated with even a modest percentage of this insulation, a near catastrophic level of property damage and personal injury could result.

Insulation can be added to existing homes in a number of ways. If the space to be insulated is exposed—an unimproved attic for example—the homeowner is likely to install fiber glass batts or blankets or pour in loose fill cellulose or mineral wool insulation. If the space is covered, the homeowner will probably contract to have foam, cellulose, or rockwool insulation blown in through drilled holes rather than going to the expense and inconvenience of having to rip open floors or walls to install fiber glass batts.

The Federal Trade Commission estimates that over half of the retrofitting will be done by contractors using the blown or foamed-in method. Loose fill cellulose insulation is the material most used in this process. Overall, cellulose insulation, which can be blown or just poured into place, accounts for approximately 30 percent of the retrofit market, or about two million homes per year.

Each of the major types of insulation has its own characteristics and potential hazards. Fiberglass, for example, is considered non-flammable unless subjected to very high temperatures. Yet some fiber glass blankets and “batts” are sold with a kraft paper vapor barrier which burns readily. Cellulose, which is ground up paper treated with chemicals to retard fire or fungal growth, can be treated to reduce its flammability but can become highly corrosive in the process. Rock wool can trap heat, such as could be generated by a recessed lighting fixture, and ignite wood joists in an attic.

On February 21, 22, and 23, 1978, the Oversight and Investigations Subcommittee held public hearings on home insulation. The hearings focused on cellulose insulation which is capturing an increasing share of the total market because of its peculiar suitability for retrofits. The Subcommittee's interest in cellulose was further enhanced by the near exponential growth of cellulose manufacturers in the past few years.

In 1976, there were roughly 100 firms with 125 plants. There are now over 350 firms and more than 500 plants. The exact numbers are unknown because no one has been able to keep pace with the expansion. In the Dallas metropolitan area, for example, the number of manufacturers has grown from 1 to 12 in the past twenty months.

Many of the new cellulose manufacturers purchased their machines and chemicals from so-called “turnkey” companies, who sell a ready-

to-operate cellulose manufacturing facility to persons with uncertain levels of technical expertise.

The industry's growth problems have been further compounded by the shortage of boric acid, one of the traditional fire retardant chemicals. The resulting fire danger from improperly or insufficiently treated cellulose is real even though reliable statistics on the contribution of cellulose to fires do not exist on a national basis.

In Michigan, for example, an average of 80 fires a year have been reported in which cellulose was identified as the first material ignited, according to the Michigan Department of Public Safety and Health. Data collected by the National Fire Protection Association shows a total of 496 such fires in only two States—California and Ohio—in a period of 15 months. Those reports do not contain any information on fires fueled by insulation but in which another material ignited first.

Acknowledging that most State and local jurisdictions lack standards for insulation, and that the Federal government should act quickly to fill this vacuum, we still have only begun to scratch the surface of the problem. The Congress must next decide on the details of the standards and how best to enforce it.

The Record developed by the Subcommittee during its three days of hearings on home insulation provides a basis for considering such legislation. Witnesses who appeared before the Subcommittee included representatives for three major cellulose manufacturers, the owners of a company that sells portable insulation manufacturing plants that can be transported to the job site on the back of a truck, plus officials of Underwriters Laboratories, a major private testing organization, and representatives from the Tennessee Valley Authority, who testified concerning that utility's experience with home insulation and the owner of a small, cellulose manufacturing company.

Government officials included Michael Pertschuk, Chairman of the Federal Trade Commission, who provided the Subcommittee with an overview of the cellulose insulation industry and the FTC's efforts to remedy current consumer abuses in this rapidly expanding industry. Testimony was also received from John O'Leary, Deputy Secretary of the Department of Energy, relative to the Department's responsibilities in the area of home insulation and from government representatives of the General Services Administration, who testified concerning the GSA's proposed new standards for insulation for use by the Federal Government in purchasing insulation for government buildings.

Taken as a whole, the testimony received by the Subcommittee shows the following:

1. The need for a mandatory, enforceable, federal standard for cellulose insulation.

2. That the absence of such a standard has created a situation in which consumers, and installers are without the means of determining the safety and the quality of cellulose home insulation.

3. That an undetermined, but significant, percentage of cellulose insulation presents an unreasonable danger to life and property in terms of fire safety and corrosion.

4. That the existing GSA and American Society for Testing and Materials standards for cellulose insulation, which have been adopted by many cellulose manufacturers, are deficient in protecting against



fire and explosion, and in specifying the precise manner in which certain of the test procedures are to be administered.

5. That fiber glass insulation batts or blankets with untreated Kraft paper vapor barriers constitute an unreasonable fire safety hazard.

6. That the Consumer Product Safety Commission has been derelict in failing to set safety standards for various types of insulation.

7. That the Administration, while encouraging people to add insulation to their homes, has been similarly remiss in failing to initiate actions necessary to provide consumers with a reasonable level of assurance concerning the safety and quality of home insulation.

8. That Underwriters Laboratories testing and inspection program for cellulosic insulation is deficient in permitting manufacturers to refer to UL in their advertising without having had all of their production checked by UL.

### *Recommendations*

Based on the record developed by the Subcommittee in public session and four months of Subcommittee staff investigation, the Subcommittee offers the following recommendations:

1. The Congress require the Consumer Product Safety Commission to enact a mandatory standard for cellulosic loose fill insulation.

2. That the Federal standard for cellulosic loose fill material be based on the proposed new General Services Administration's standard HH-I-515D, which includes a smouldering test and substitutes a radiant panel test for the Steiner tunnel test in determining surface burning characteristics.

3. That the CPSC promulgate an HH-I-515D based standard for loose fill cellulose insulation, with such technical changes and revisions as may be considered necessary by the CPSC, within 90 days of passage of the legislation.

4. That the new D based standard become effective 120 days after promulgation by the CPSC.

5. That as an interim, 210-day measure, the CPSC be required to adopt the existing GSA HH-I-515C standard for loose fill cellulose insulation.

6. That all manufacturers of loose fill cellulose insulation intended for home use be required to certify that their product meets the applicable CPSC standard and to label their bags accordingly.

7. That the legislation include a requirement that all cellulose manufacturers, within one year of the legislation, subscribe to a CPSC approved, privately operated, third party laboratory testing program to include periodic, unannounced inspections of the cellulose manufacturing facilities and production.

8. That the third party independent testing and inspection program be modeled after, but not necessarily identical to the existing Underwriters Laboratories program, in providing for a minimum of four unannounced factory visits and inspections per month, the results of which to be furnished to the CPSC on a monthly basis for use in its enforcement program.

9. That cellulose insulation manufacturers be permitted to advertise and to describe on their bags the results of the Steiner tunnel test for a period of 18 months after passage of the legislation to permit state and local building inspectors, and other concerned officials, to



become familiar with the new radiant panel and smouldering tests, as included in the new federal standard.

10. That the CPSC mandate a standard for fiber glass insulation batts or blankets requiring that all Kraft paper vapor barriers be fire tested.

### *Senate Legislation*

Senate Bill S. 2401, passed on January 23, 1978, requires the Consumer Product Safety Commission to adopt, as an interim product safety measure, the existing GSA HH-I-515C standard for cellulose.

The Consumer Product Safety Commission, at its discretion and after consultation with the Department of Energy and such other governmental and private bodies as it desires, is empowered to adopt an improved standard at any point in the future. Unlike the Subcommittee's recommendation, the Senate Bill does not require adoption of a permanent standard at a date certain.

## CHAPTER I

*Safety Issues*

Consumer safety is the major problem associated with home insulation. No one to the Subcommittee's knowledge disputes the proposition that untreated, or improperly treated ground up newspaper presents an unreasonable fire safety hazard when used as an insulating material.

As stated by the Chairman of the Task Force on Fire Safety of Insulation of the National Bureau of Standards, "the basic thesis for fire safe use of insulation is that the addition of insulation should not increase the normal and expected level of fire risk to the resident."<sup>1</sup>

Corrosion-causing insulation can similarly present a hazardous situation in the event of corroded electrical wiring or junction boxes.<sup>2</sup> The Subcommittee has documented 43 incidents in California where cellulose insulation is known to have corroded copper electrical wiring, although no fires occurred.<sup>3</sup> In addition to the safety hazards associated with corroded electrical wiring, improperly treated cellulose insulation can cause building damage sufficient to pose a safety hazard as occurred when cellulose insulation caused the total collapse of a warehouse in Wisconsin.<sup>4</sup>

The primary safety concern relating to home insulation, however, is that of fire safety. One issue about which relatively little is known involves the tendency of insulation to "super insulate" electrical wiring and connections causing them to operate at temperatures in excess of their rated capacity. On that point, Jack Bono, a Vice President of Underwriters Laboratories, in a March 1977 U.L. sponsored meeting of industry officials noted that the:

... wide spread utilization of more efficient thermal insulation may have adverse consequences on the performance of electrical wire and cables, and other electrical devices. Since such devices generate heat, and since wire and cables rely on the integrity of electrical insulation for their safe and efficient operation, it seems obvious that any proposed change in operating conditions which might cause overheating of conductor electrical insulation, with possible resulting damage, requires a careful review. Such a review process apparently has not yet been initiated.<sup>5</sup>

Unfortunately, the review called for by Mr. Bono concerning this potentially serious and far reaching problem has barely begun, as evidenced by the following colloquy between Subcommittee staff

<sup>1</sup> Memorandum Progress Report to the Files from D. Gross, Chairman, Task Force on Fire Safety of Insulation, National Bureau of Standards, October 4, 1977. (Appendix I)

<sup>2</sup> Underwriters Laboratories, Inc., "Report on Meeting Concerning the Effect of Thermal Insulation on Electrical Building Wire and Cables," March 30, 1977. (Appendix II)

<sup>3</sup> Memorandum to Chairman John E. Moss from Subcommittee staff, "Additional Reports of Corrosion Attributed to Cellulose Insulation," February 21, 1978. (Appendix III)

<sup>4</sup> Memorandum to Chairman John E. Moss from Energy Subcommittee staff, "Cellulose Insulation and Corrosion Problems in Wisconsin," February 17, 1978. (Appendix IV)

<sup>5</sup> UL Minutes, page 2. See also Draft study Center for Building Technology Institute for Applied Technology National Bureau of Standards, "Exploratory Study of Temperatures on Residential Branch Circuit Wiring Encased in Thermal Insulation," February 1978.

and Dr. Maxine Savtiz, Director of the Department of Energy's Division of Buildings and Community Systems:

STAFF. Dr. Savtiz, as the Department of Energy's technical person in the area of home insulation, are you personally persuaded that insulation, upon coming into contact with electrical wire and junction boxes will not cause the wire to overheat and produce a fire danger?

Dr. SAVITZ. We have been sponsoring a study to investigate what is the cause and effect of having insulation on wires.

Some preliminary results from that study, which we have just received and are reviewing, indicate that the wire does heat up. In those tests, there was no indication that fire occurred, but we don't know over the long time.

This is an issue that has to be looked at thoroughly.

STAFF. So the preliminary results are that insulation, regardless of the quality of insulation, can cause electrical wiring to overheat.

So at this point, Dr. Savtiz, we can't rule out the possibility that fires may—and I emphasize “may”—occur in an undetermined number of homes as a result of wire overheating, regardless of the quality of the insulation. Is that correct?

Dr. SAVITZ. We don't know yet.

I want to reemphasize that in those tests that they did, there were no fires that occurred, but there was overheating of the wire.<sup>6</sup>

In view of the potential hazards associated with dangers of overheated electrical wiring from contact with various types of insulation, Chairman Moss has instructed the Subcommittee staff to thoroughly investigate the matter as a prelude to holding a possible public hearing.

The traditional concern relative to the fire hazards of insulation goes not to the effect of the insulation on electrical systems as discussed above, but rather to the performance of the insulation in an actual fire situation. Since there are no reports of spontaneous combustion concerning home insulation, the issue thus is one involving the ability of insulation to withstand a potential fire source, such as an electrical short or heat build up from a recessed lighting fixture. Those safety considerations relate in turn to the efficacy of existing and proposed insulation fire safety standards and the means by which such standards should be enforced.

There are no mandatory performance standards for home insulation. The GSA as the purchasing arm of the Federal Government requires that all insulation purchased for direct use by the Federal Government meet GSA standard HH-1-515C for loose fill cellulose or wood fiber insulation, HH-1-1030A for pneumatic or poured mineral fiber insulation and HH-1-521E for mineral fiber blanket type insulation. The GSA is in the process of revising those three standards.

Most insulation manufacturers claim that their product meets the current GSA or similar American Society of Testing Materials specifications.

<sup>6</sup> Hearings on Home Insulation, Subcommittee on Oversight and Investigations, Committee on Interstate and Foreign Commerce, February 21, 22 and 23, 1978. Serial No. 95-81, at 312. [Hereinafter cited as *Hearings*.]

Putting aside for the moment the question of whether insulation manufacturers are indeed voluntarily meeting the GSA specifications, serious questions exist concerning the relevance of those specifications to fire situations that are likely to occur in the home. In the case of cellulose insulation, the major source of concern is heat build up from recessed lighting fixtures or electrical wiring. In both cases, one of two things may happen. The insulation may literally burst in flame, or the material may smoulder for hours igniting various combustibles in its path. Neither the existing GSA nor ASTM specifications test the smouldering properties of cellulose insulation and as such are of no use in determining the extent to which cellulose insulation will propagate a smouldering fire. Rather, they focus on various indices as determined in a 25 foot Steiner tunnel test.

The tunnel test was developed by Underwriters Laboratories in 1950 for use in testing the surface burning characteristics of ceiling and wall coverings, such as acoustical tiles and decorative paneling.<sup>7</sup> "But through some strange media, as time passed on, it was passed on to everything that was associated with fire retardancy,<sup>8</sup> including cellulose insulation in 1973.

In testing the surface burning characteristics of cellulose insulation, 36 square feet of material is held in place on the ceiling of the test tunnel by means of a wire screen and exposed to a flame. Of the three characteristics noted, "the most quoted surface burning characteristic for cellulose insulation is flame spread."<sup>9</sup> The conventional wisdom among many in the industry is that a flame spread of less than 25 is excellent and that a flame spread of under 50 is satisfactory. From this, there has developed a system whereby cellulose insulation with a flame spread of less than 25 is classified as a Class I product and that insulation with a flame spread between 25 and 50 is defined as a Class II product.

The flame spread numbering system is based on a comparison with the surface burning characteristics of untreated red oak flooring. The latter, when tested for ten minutes in the Steiner tunnel, obtains a flame spread rating, or linear distance of 100, as compared to zero for asbestos cement board. A flame spread of 25 for cellulose insulation means, therefore, that the flame spread was one-fourth that of the red oak flooring.

A procedural problem that has only been resolved as of January of this year, concerned the fire retardant effect of the screen which holds the cellulose in place. Underwriters Laboratories multiplied the flame spread by a factor of 1.47 to correct for the effect of the screen. Other testing laboratories, however, did not. Until January, the same material could be rated in different classes depending on which laboratory performed the test.

Ideally, the laboratory fire test results should closely correspond to conditions likely to occur in the home. Since it is not practical to test cellulose in real attics, one must strive to fashion a laboratory test that most clearly resembles situations likely to be encountered in the

<sup>7</sup> Underwriters Laboratories "Statement on the Development, Use, and Significance of the UL 723 Tunnel Test Standard." (Appendix V)

<sup>8</sup> Testimony of Roger F. Carroll, Jr., Assistant Commissioner, Office of Standards and Quality Controls, Federal Supply Service, General Services Administration, *Hearings*, *supra* note 6, at 371. For a listing of materials tested by Steiner tunnel see UL statement on Tunnel Test.

<sup>9</sup> Paul Lancer, Consumer Product Safety Commission staff, "Engineering Analysis of Existing Flammability Standards and Test Methods for Cellulose Insulation," December 12, 1977, p. 5. Fuels contribution and smoke development are also measured by the tunnel test. (Appendix VI)



home. Since people do not live in tunnels, the question then becomes one of relevance between the results obtained in the tunnel test and those likely to occur in a home. Given the crude relationship between a 25 foot tunnel and residences, safety experts have begun to question the overall relevance of the Steiner tunnel test which uses red oak, a hard, high density material, to soft materials of low density, such as cellulose insulation. According to recent research, "the potential for rapid spread of some low flame spread classification (FSC) low density materials is evident from observations of the flame propagation along these materials during the tunnel test, but is not adequately reflected in the flame spread classification."<sup>10</sup> The carpet industry, for example, concerned over the relevance of Steiner tunnel test data, has abandoned the tunnel in favor of a radiant panel test.<sup>11</sup> More recently, the Steiner tunnel was shown to be invalid for various low density fire retardant plastics.<sup>12</sup>

Concerned over the relevance of the Steiner tunnel test methodology, as employed in the United States, the Canadian Government has recently required that cellulose samples be placed on the floor of the tunnel to more closely resemble an attic situation. The results of that change are startling. In one instance, cellulose that received a 20 rating under the United States test method received a flame spread rating of 127 when tested on the floor of the tunnel.<sup>13</sup> The failure of the Steiner tunnel to accord with reality has also been demonstrated by the National Bureau of Standards. In a test attic which the NBS constructed, a Class I rated cellulose burned readily when the sample was preheated to 160°F. That temperature approximates summer attic conditions in many parts of the United States, yet is somewhat more severe than that called for in the Steiner tunnel test.<sup>14</sup>

Tunnel test data, moreover, can vary from tunnel to tunnel. In an interlaboratory test involving eight materials and eleven tunnels, researchers found a variation between tunnels of 43% for flame spread which was attributed to differences in tunnel construction and operating procedures.<sup>15</sup> A variation of that magnitude can easily make the difference between a Class I and Class II rating, or between a Class II and an "unacceptable" rating.

The existing test methodology is further flawed because cellulose manufacturers are permitted to specify the density at which their product is to be tested. One witness before the Subcommittee, Brian Derbyshire, Technical Service Manager of Thermtron Products, Inc., a major Fort Wayne, Indiana, cellulose manufacturer, testified that this loophole could permit a manufacturer to obtain a more acceptable flame spread rating than that which would result if he were required to have his product tested at its true density.<sup>16</sup>

In sum, the testimony received by the Subcommittee highlights the myriad deficiencies of the current method of assessing the flammability of cellulose. Among other things, the absence of a smouldering test, the irrelevance of the tunnel test data, and the arbitrary nature of the

<sup>10</sup> National Bureau of Standards Technical Note 945, "An Investigation of the Fire Environment in the ASTM E-84 Tunnel Test," p. 1 (August, 1977). (Appendix VII)

<sup>11</sup> *Hearings*, *supra* note 6, at 370.

<sup>12</sup> *Id.* at 376.

<sup>13</sup> Information provided the Subcommittee by Dr. Michael Desusa, Fire Research Division, National Research Council of Canada.

<sup>14</sup> National Bureau of Standards, "Description of Film Strip on Fire Tests of Insulation: n an Attic Mock-up," *Hearings*, *supra* note 6, at 295-96.

<sup>15</sup> NBS Note 945, p. 3.

<sup>16</sup> *Hearings*, *supra* note 6, at 286.



tunnel test procedures indicate that the existing GSA HH-I-515C specification for loose fill cellulose insulation cannot be used as a basis for establishing a meaningful Federal standard.

The existing GSA specification HH-I-521 for fiber glass is also inadequate since it permits fiber glass manufacturers to remove the kraft paper vapor barrier that is glued to one side of the fiber glass blankets. A film produced by the National Bureau of Standards and shown at the hearing vividly demonstrates the hazards of this approach. In a prototype attic situation, a fiber glass blanket with a slit paper backing was shown to have burst into an inferno-like fire within minutes of ignition. The industry contention that the paper vapor barriers do not pose a safety hazard because fiber glass blankets are installed with the paper vapor barrier down does not apply in all instances. For example, an advertisement in the current Montgomery Ward catalog which features fiber glass rolls with decorative paper vapor barriers, encourages unwary homeowners to "[d]ecorate as you insulate with kraft-faced rolls . . . Ideal when facing will be exposed . . ." <sup>17</sup>

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<sup>17</sup> Montgomery Ward, Spring and Summer 1978 Catalog, p. 680.

## CHAPTER II

*Toczek & Sons*

The strong demand for insulation in the past few years has created a host of "turn key" manufacturers, persons who have purchased ready to operate cellulose manufacturing plants. Little or no technical expertise is required as a precondition to purchase, and many turn key operators have only a rudimentary knowledge of the machinery, the materials, and the cellulose manufacturing process.

Turn key machines range from the primitive to the sophisticated. The discussion following concerning Toczek & Sons of Aurora, Colorado, a supplier of portable insulation manufacturing plants, is not intended to apply to other turn key operations.

Nonetheless, the problems which appear in perhaps their rawest form in the Toczek case raise valid concerns about other turn key manufacturers that have recently entered the field.

The testimony of Ronald Toczek and Stanley Finkel, co-owners of Toczek & Sons, is illustrative of the darkest side of the cellulose industry and emphasizes the need for prompt enactment of a mandatory standard for home insulation.

Messrs. Toczek and Finkel sell a \$6,000 portable insulation manufacturing unit that can be transported to the job site on the back of a truck. The paper is fed into one end of the machine, ground up and simultaneously mixed with chemical and then blown directly in the home. The Toczek machine, the T1610, was the only known portable insulation plant on the market when it was introduced approximately one year ago. Since then, according to Mr. Toczek, two other companies have begun to market similar units.<sup>1</sup>

The concept of a portable insulation manufacturing plant that blows cellulose insulation directly into the home is dubious because of the difficulties involved in performing meaningful on site quality control tests. The need for periodic testing is especially pronounced in the case of equipment such as this which does not automatically control the ratio of chemical to paper.

According to the Tennessee Valley Authority, which has developed considerable expertise by virtue of its home re-insulation program, "Whether adequate quality control can be maintained in such a process is a question that requires serious attention."<sup>2</sup>

Given the uniqueness and the simplicity of the Toczek portable insulation manufacturing plant, one might assume that the machine was thoroughly tested prior to its being introduced into the market. Such, however, was not the case. According to Mr. Finkel, no machine was ever tested by his company for more than one continuous hour and only one home was actually insulated prior to the machine being offered for sale.<sup>3</sup> At no point in time, moreover, has the company per-

<sup>1</sup> *Hearings, supra* note 6, Chapter I, at 34.

<sup>2</sup> *Id.* at 7.

<sup>3</sup> *Id.* at 39, 44.

formed a corrosion test on insulation produced by the T 1610.<sup>4</sup> According to Mr. Toczek, "Our main concern was over building a machine that would produce a fireproof product, a fire retardent product."<sup>5</sup> The only laboratory test data obtained by Toczek & Sons was a single report prepared by United States Testing Company, Inc., on April 22, 1977, some six months after the machine was first offered for sale.<sup>6</sup> The report shows a Class I flame spread of 15. It does not, however, indicate whether the chemicals used to manufacture the sample submitted to U.S. Testing were the same as those which were supplied with the machine.

A number of the 120 or 130 persons who purchased a portable manufacturing unit from Toczek were furnished a copy of the April, 1977 U.S. Testing Company report by Toczek & Sons and were told that the test was valid for cellulose produced by their unit.<sup>7</sup> That ruse apparently not only satisfied purchasers of the Toczek unit, but a number of utilities who accepted the owners of these machines into their insulation program.<sup>8</sup> Subsequently, Toczek & Sons sent a letter to all of their customers advising them that the test was not valid for production from their machines.<sup>9</sup>

Prior to the hearing, the Subcommittee sent questionnaires to 102 persons identified by Toczek & Sons as having purchased the T 1610. At the time of the hearing, 55 completed questionnaires were returned to the Subcommittee from persons who had operated their machines. Of those only two reported having their product tested by an independent laboratory for flame spread, although others indicated that they periodically tested their product for flammability with a blow torch. The chemical formulation, and add-on recommended by Toczek & Sons—50% borax and 50% aluminum sulfate, at the ratio of 25% chemical to 75% paper—would most likely produce an acceptable flame spread provided, however, that the operator was able to maintain a consistent ratio of chemical to paper. The failure of all but one of the 55 respondents to have their product tested for corrosion is particularly unfortunate in view of the high corrosive potential the aluminum sulfate recommended by Toczek & Sons for use as a fire retardant. For example, Allied Chemical Corporation, a major supplier of aluminum sulfate, by letter of January 16, 1978, (Appendix IX), has informed all wholesalers of their product that they will no longer supply aluminum sulfate for resale to cellulose insulation manufacturers absent a statement from the cellulose manufacturers attesting that his product complies with the GSA specification for cellulose insulation.

An identical letter has been sent concerning the sale by Allied Chemical of ammonium sulfate for use in manufacturing cellulose insulation. Notwithstanding the corrosion danger, aluminum and ammonium sulfate are being used in increased amounts by cellulose manufacturers because of the sharply increased cost, and limited supply of boric acid, the traditional fire retardant used by the industry.

<sup>4</sup> *Id.* at 34.

<sup>5</sup> *Id.* at 36.

<sup>6</sup> Subcommittee Staff, "Summary of Questionnaire to Purchasers of Toczek & Sons Portable Insulation Manufacturing Plant," February 17, 1978 (Appendix VIII).

<sup>7</sup> *Id.*

<sup>8</sup> *Id.*

<sup>9</sup> *Id.*

Technically knowledgeable persons within the industry are divided concerning the suitability of sulfates for use in manufacturing cellulose. There is agreement, however, that use of a sulfate based fire retardant requires a sophisticated manufacturing and blending process.<sup>10</sup>

A review of the completed questionnaires furnished the Subcommittee suggests that the failure to adequately test product on the part of many of the purchasers of the Toczek portable insulation manufacturing unit is attributable to naivete and not to a deliberate attempt to sell a potentially hazardous product.

The purchasers of the Toczek machines were small business operators, home improvement contractors, store owners, and the like, who were attracted by Toczek's questionable advertising, which held out the promise of earning as much as \$400 and then \$300 per day manufacturing and installing cellulose.<sup>11</sup> None of the 55 persons surveyed by the Subcommittee ever came close to making that much money with their insulation making machines, and few appeared even to have anything other than a rudimentary knowledge of cellulose and cellulose testing.

The experience of a Mr. Russell Moline of Galva, Illinois, is typical. According to Mr. Moline:

We are honest people and desire to make a good product. The machine was represented to manufacture 300 pounds per hour and to apply 25 percent chemical to 75 percent paper. It will not do this unless altered. The salesman said we didn't need any tests. We understood we could use their tests. But a few days after purchase, they sent a letter saying we could not.

The machine was very poorly put together. We have had to replace double nut bolts and replace metal work because of a lot of vibration. The product is fireproof, and looks good but the machine only produces 100 to 150 pounds per hour.

We have called the factory several times because they said we could call if we had trouble. The last time a person who called himself Toczek said, "Goodbye, sucker," and hung up.<sup>12</sup>

In the absence of a mandatory Federal standard for home insulation, Toczek & Sons thus were found by the Subcommittee to have been able to sell between 120 to 130 portable insulation making machines to persons, who in the main, had no knowledge of what they were getting in to and who accordingly set about producing and installing a potentially hazardous and virtually untested product to unsuspecting homeowners.

<sup>10</sup> *Hearings, supra* note 6, Chapter I, at 249 and 293-4.

<sup>11</sup> *Id.* at 37.

<sup>12</sup> *Id.* at 65.



## CHAPTER III

*Established Cellulose Insulation Manufacturers*

One of the major conclusions to be drawn from the record of the Subcommittee is that the manufacturer of hazardous or inferior cellulose insulation is not confined to new, turn key type manufacturers. Indeed, the record suggests that major, long established cellulose manufacturers have been negligent in assuring the quality and the safety of their product. The proper manufacture of cellulosic insulation is not simply a matter of grinding up newspaper and mixing in some chemical. Rather, it requires an exacting manufacturing process to assure the proper ratio of chemical to newspaper for each and every bag of production. For example, the chemical flow must be automatically regulated to adjust to differences in the rate in which the ground up newspaper is fed into the chemical hopper. The quality of the paper, the size of the chemical particles, and the grind of the paper also strongly influence the quality and the consistency of the final product.

Absent an electronically controlled chemical feed system, variations in the rate in which the newspaper is manually introduced into the grinder will result in an uneven distribution of chemical. In that event, some bags of insulation could lack the necessary fire retardency while others might contain too much chemical, which can cause the cellulose to support corrosion in the presence of moisture.

The difficulty in assuring a consistent ratio of chemical to paper is further compounded by variations in the density of the newspaper due to the type of wood used to produce various newspaper. Other key detriments in the manufacture of cellulose insulation involve the consistency of the chemicals, "the way you put and how much material you put through a hammer mill operation, how much air volume there is, the configuration of the hammers, the size of the screen," etc.<sup>1</sup> Failure to grind the chemical fire retardents to a fine enough state and to introduce the paper in a correct manner can cause the chemical to separate out of the insulation and to remain in the bag, an obvious fire hazard.<sup>2</sup>

Consistency of product is crucial, therefore, to the proper manufacture of cellulose insulation. In discussing the requirements for a valid testing program for cellulose insulation, Michale Pertschuk, Chairman of the Federal Trade Commission, observed that:

It is not the same kind of testing problem as when you are dealing with a design of a product where the test of the design of a prototype product would give an accurate picture of the performance of that product. It is a test that is required to monitor a process.<sup>3</sup>

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<sup>1</sup> *Id.* at 284.

<sup>2</sup> *Id.* at 157.

<sup>3</sup> *Id.* at 125.



The current outside testing procedure employed by the overwhelming majority of cellulose manufacturers is one wherein the manufacturer submits a product sample to an outside laboratory on a one-time or infrequent basis, which provides no assurance concerning the ability, or the willingness, of the manufacturer to produce a consistently acceptable product. The one-time test procedure provides an opportunity, moreover, for unscrupulous manufacturers to submit an unrepresentative sample to an outside laboratory to obtain a favorable laboratory report for promotional uses or even submitting products made by one of their competitors.

Chairman Pertschuk related how the FTC has initiated action against a cellulose insulation manufacturer following a determination that the company, ATI of Portland, Oregon, had obtained a laboratory report based on product manufactured by another manufacturer. The investigation commenced after a fire involving ATI insulation broke out during installation in a dormitory at Portland State College.<sup>4</sup>

The Subcommittee hearing further brought to light instances in which independent testing laboratories were found wanting. One cellulose manufacturer submitted to the Tennessee Valley Authority, for purposes of participating in that utility's home re-insulation program, a report from Terralab of Salt Lake City, Utah. The report concluded that the product in question "meets or exceeds the requirements of ASTM C-739 for Class I loose-fill cellulosic insulation." Yet, the smoke generation number of 155 included in the report was well in excess of the 50 limit set by the ASTM test.<sup>5</sup>

In another instance, American Interplex Corporation, an independent laboratory in Little Rock, Arkansas, tested samples of cellulose insulation manufactured by three different manufacturers who sought to participate in the TVA program. As noted by a TVA official before the Subcommittee, "The test results were identical for all three test reports on the three separate materials, which was, in our view, beyond our comprehension how it could be coincidental."<sup>6</sup>

Additional information presented at the hearing further demonstrates the fallacy of relying on a single, or even handful of independent laboratory reports to indicate the safety or quality of cellulose insulation. In January 1977, the Energy Research and Development Agency (ERDA), which is now included in the Department of Energy, issued a report, "Survey of Cellulosic Insulation Materials" based on the testing of 19 off-the-shelf samples of cellulose insulation obtained from four geographic areas.<sup>7</sup> The results of that study are hardly reassuring. On the positive side, the flame spread data reported by the manufacturers—to the extent that flame spread is a useful indices—were in good agreement with those determined by ERDA.

On the negative side, however, and despite the fact that most of the manufacturers could doubtlessly produce favorable laboratory reports, the report showed the following:

1. Most of the eight samples tested by ERDA had a lower R or thermal resistance value than claimed by the manufacturer, meaning that the purchasers in effect ended up with between 11 and 63% less insulating effect than he or she paid for.

<sup>4</sup> *Id.*

<sup>5</sup> *Id.* at 21.

<sup>6</sup> *Id.* at 22.

<sup>7</sup> Energy Research and Development Administration, "Survey of Cellulosic Insulation Materials," January 1977. (Appendix X)

2. Separation of fire retardant chemicals occurred in 13 of 19 samples surveyed after normal handling.

3. Six of the 19 samples exceeded the moisture absorption criteria of the standard industrial test methodology, a condition that can promote corrosion or possibly reduce the effectiveness of the insulation.

4. Six of the 19 samples supported fungal growth, a condition likely to reduce the effectiveness of the insulation by destroying the fiber structure while providing a source for fungal spores that could pose a health hazard.

5. Eleven of the samples produced excessive general corrosion.

Because some of the samples tested by ERDA were obtained from interested community groups, who did not furnish ERDA with the manufacturers' names, it is not possible to identify all the manufacturers involved in the ERDA study. The Subcommittee staff, based on a review of ERDA files was able, however, to identify most of the companies involved. The companies whose product was found unsatisfactory are noted in Appendix XI.<sup>8</sup> A review of those failures demonstrates that the problems within the cellulose industry are not confined to small, new entrants into the business as is frequently suggested by the older, more established manufacturers.

A similar conclusion can be learned from a recent Department of Energy sponsored study by the Minnesota Energy Agency. The study involved the testing of insulation removed from homes in Minnesota. Of 21 cellulose samples tested, four displayed "little if any fire retardant properties" and involved cellulose manufactured within the past one or three years.<sup>9</sup> Two of the three companies involved, U.S. Fiber Corporation of Delphos, Ohio, and Diversified Insulation of Hamel, Minnesota, are among the oldest and largest cellulose manufacturers.

The Minnesota Energy Agency based its determination concerning the lack of fire retardancy on a test which it described as follows:

A flame test was performed on cellulosic materials by forming a clump of the material into a hemisphere about two and one half inches in diameter, and dropping a lighted paper match into a depression on the top of the sample and observing any tendency of the material to ignite and sustain combustion.<sup>10</sup>

In testimony before the Subcommittee, Robert C. Anderson, Director Product Development of Diversified Insulation, who served on the Technical Review Committee for the Minnesota study, described this test method as a "quick-and-dirty field type test" that is a "fairly decent indication" of the safety of the product.<sup>11</sup>

The testimony of U.S. Fiber Corporation before the Subcommittee was particularly troublesome. U.S. Fiber is one of the nation's largest cellulose insulation manufacturers with plants in four states and plans to double its production over the next three years.<sup>12</sup>

In testimony before the Subcommittee, Thomas J. Miller, Vice President of Research and Development for U.S. Fiber, maintained

<sup>8</sup> Memorandum to Chairman Moss from Subcommittee Staff, "Manufacturers of Cellulose Insulation that Failed Tests Conducted by ERDA," February 17, 1978. (Appendix XI)

<sup>9</sup> Minnesota Energy Agency, "Minnesota Energy Agency Insulation Testing Program," pp. V 18-20 (draft November 1977).

<sup>10</sup> *Id.* at 8.

<sup>11</sup> *Hearings*, *supra* note 6, Chapter I, at 242.

<sup>12</sup> *Id.* at 253.

that U.S. Fiber cellulose insulation passes both the existing GSA voluntary industry standard and the new proposed GSA standard.<sup>13</sup> In defense of that proposition, U.S. Fiber supplied the Subcommittee with a number of independent laboratory test reports attesting to U.S. Fiber's conformity with the current GSA specifications. Other information reviewed by the Subcommittee suggests otherwise.

In the Minnesota Field Study, for example, one of three samples of U.S. Fiber product was determined to contain little if any fire retardant properties.<sup>14</sup> In the January, 1977 ERDA study, two U.S. Fiber samples when tested for corrosion totally destroyed the metal test coupons, a situation which Mr. Miller indicated could damage water pipes, electrical wires and other building components.<sup>15</sup> That same study included U.S. Fiber's product as among the worst offenders in terms of chemical separation, moisture absorption, and support of fungal growth.<sup>16</sup>

Upon learning that major cellulose manufacturers frequently test the competition's product, the Subcommittee subpoenaed those test results from five cellulose manufacturers, including U.S. Fiber. Those tests indicate that most of the samples tested had a flame spread of less than 50 based on a crude test methodology designed to roughly conform to the results of the 25 foot Steiner tunnel test. The only major exception were tests conducted by U.S. Fiber. Of the 47 "burn tests" performed, 17 were judged by U.S. Fiber to have a flame spread greater than 50, considered the upper limit by industry.<sup>17</sup>

In the case of corrosion, the majority of the samples tested by the five manufacturers failed the standard industry test. Of the many companies whose product was tested by rival firms for corrosion, U.S. Fiber was conspicuous with regard to its failure to pass.

Incel Corporation of Bluffton, Indiana, for example, tested U.S. Fiber loose fill cellulose insulation on ten separate occasions since January 1, 1975.<sup>18</sup> After passing the first two corrosion tests in early 1976, U.S. Fiber's product failed the next eight. Thermtron Corporation of Muncie, Indiana, tested U.S. Fiber cellulose insulation for corrosion nine times since March 1974 and in all instances the product failed.<sup>19</sup> Diversified Insulation submitted three samples of U.S. Fiber products to an independent testing laboratory in July 1977 which reported all three samples as failing the corrosion test.<sup>20</sup>

In addition to the potential safety problems associated with corrosive insulation, which can damage electric wiring or equipment as has been documented in California,<sup>21</sup> improperly treated or manufactured cellulosic insulation can cause severe property damage. Reference has been previously made to a situation in Wisconsin where a cheese warehouse collapsed following installation of cellulose insulation. An

<sup>13</sup> *Id.*

<sup>14</sup> Minnesota Field Study, pp. V 19-20.

<sup>15</sup> *Hearings, supra* note 6, Chapter I, at 253-4.

<sup>16</sup> "Manufacturers that Failed ERDA Tests."

<sup>17</sup> *Hearings, supra* note 6, Chapter I, at 276.

<sup>18</sup> Subcommittee Staff, "Results of Incel Corp., Bluffton, Indiana, Corrosion Tests of Cellulose Insulation Manufactured by U.S. Fiber, Delphos, Ohio, January 1975 to February 1978," *Hearings, supra* note 6, Chapter I, at 276.

<sup>19</sup> Thermtron Products, Inc., "Summary of Tests Conducted on U.S. Fiber Produced Cellulosic (loose fill) Insulation," *Hearings, supra* note 6, Chapter I, at 265.

<sup>20</sup> *Id.* at 267-70.

<sup>21</sup> Memorandum to Chairman John E. Moss from Subcommittee staff, "Additional Reports of Corrosion Attributed to Cellulose Insulation," February 21, 1978. (Appendix III)



investigation by the state Safety and Building Division determined that the insulation contained aluminum sulfate, a fire retardant, and that moisture had combined with this chemical to form sulfuric acid which destroyed the metal studs that supported the roof.<sup>22</sup>

Subsequent investigation revealed an identical problem with a second metal building which lead to an inspection of all similar buildings insulated with Pal-O-Pak Insulation. The investigation revealed that "wherever moisture had been introduced into the insulation, oxidation of the metal panel occurred." Of 41 buildings, 20 were found to have suffered corrosion damage half of which were considered serious.<sup>23</sup>

Other examples of corrosion property damage attributed to cellulose insulation included the following:

1. Three years after it was installed, Pal-O-Pak insulation severely corroded the bathroom copper piping in an apartment in Rochelle, Illinois.

In Utah, another brand of cellulose insulation destroyed the copper piping of a home within only three months of construction.<sup>24</sup>

2. Electra Manufacturing Corporation of Holland (Toledo), Ohio, supplied cellulose insulation to contractors in the Flint, Michigan area who contend that they used this material to insulate mobile homes.

Within approximately one year, some 100 mobile homes developed a pitting or corrosion on the outside wall. Damage has been estimated at about \$2,000 per home. Electra subsequently advised its customers that "the use of cellulose fiber insulation as a re-insulator of mobile homes is not recommended at this time."<sup>25</sup>

3. U.S. Fiber Corporation testified that it has paid in out-of-court settlements \$13,000 and \$180,000 in cases involving corrosion attributed to its spray-on cellulose. U.S. Fiber is currently being sued by Golden Giant Company, a warehouse manufacturer which alleges that this product caused serious corrosion damage to some 38 metal buildings.<sup>26</sup>

<sup>22</sup> Memorandum to Chairman John E. Moss from Energy Subcommittee staff, "Cellulose Insulation and Corrosion Problems in Wisconsin," February 17, 1978. (Appendix IV)

<sup>23</sup> *Id.*

<sup>24</sup> Copper Development Association, "Investigation Report: Corrosive Attack by Moist Cellulosic Insulation," January 6, 1978. *Hearings, supra* note 6, Chapter I, at 164.

<sup>25</sup> Memorandum to Chairman John E. Moss from Subcommittee staff, "Mobile Home Corrosion and Electra Manufacturing Corp. Cellulose Insulation," February 17, 1978. *Hearings, supra* note 6, Chapter I, at 178.

<sup>26</sup> *Id.* at 271-72.

## CHAPTER IV

*Underwriters Laboratories*

Underwriters Laboratories is a private testing organization headquartered in Northbrook, Illinois, and operating in all 50 states. UL describes its purpose as "testing for public safety."<sup>1</sup> UL's test work involves the testing of products to determine compliance with applicable safety standards and a factory follow-up inspection service whereby "Trained inspectors observe and countercheck production control methods that the manufacturer uses to determine compliance with UL's safety requirements."<sup>2</sup> Under that program, the official UL mark on a product indicates that the product complies with UL's requirements and is covered under UL's factory follow-up service program. Over 245,000 domestic factory inspections were made by UL inspectors in 1976 and over 1.8 billion labels were issued for products in some 4,000 categories.<sup>3</sup>

Included among UL's wide ranging testing program is a service that can be purchased by manufacturers of loose fill cellulose insulation which involves two related test programs. The first includes a fire classification program which permits manufacturers to indicate by means of a UL label on each bag of production their fire classification as determined by UL. The second program covers additional test requirements relating to corrosion, thermal resistance, moisture absorption, odor emission, and other factors as noted on the bag.

In order to use one or both of those UL labels, a cellulose manufacturer is subjected to a review which includes the following, as described by UL:

1. An initial factory inspection to determine the ability of the manufacturer to produce a consistent product with a given chemical formulation.

2. The collection of samples at the time of the initial factory visit for testing by UL.

3. A continuing series of unannounced factory visits to review the manufacturer's quality control records, test procedures, manufacturing process, and chemical formulation.

4. A once per quarter or once per year test of samples selected by UL for moisture absorption, thermal resistance, odor emission, and fire classification. The frequency of those tests depends on a number of factors including the type of inhouse fire testing performed by the manufacturer and whether he uses a premixed chemical formulation which requires that samples be tested by UL on a quarterly basis. At no point after the initial UL round of tests does UL conduct corrosion tests on a manufacturer's product.<sup>4</sup>

If the product is in compliance with the follow-up service procedure, a manufacturer is permitted to apply the UL label to his production.

<sup>1</sup> *Id.* at 330.

<sup>2</sup> Underwriters Laboratories, Inc., "1976 Annual Report," p. 13.

<sup>3</sup> *Id.*

<sup>4</sup> *Hearings*, *supra* note 6, Chapter I, at 332.



According to UL, if the manufacturer is labeling his production on a continued basis, the frequency of inspection is two visits per month. The minimum number of inspections is one per quarter.<sup>5</sup>

At the present time, 39 cellulose manufacturers subscribe to the UL fire classification program, and 15 to the broader program covering corrosion, thermal resistance, moisture absorption, odor emission, etc.<sup>6</sup> The present UL program, its alleged technical deficiencies notwithstanding,<sup>7</sup> has caused considerable confusion in an already confused market. That is particularly unfortunate given the reliance that consumers place on the UL name.

Under the current UL inspection and follow-up test service, manufacturers upon being given initial approval by U.L., based on a plant inspection and product test, are "listed" by U.L. as being able to produce U.L. "labeled" cellulose. Upon being listed, a manufacturer can maintain his UL listing for as long as two years without putting a UL label on a single bag of production. To maintain his U.L. listing for an additional two years, the manufacturer has only to label a single bag of production.

That is significant because the U.L. follow-up inspection program is in effect only at such times as the manufacturer is using the U.L. label on his product. Once listed by U.L., however, the manufacturer is free to advertise his product as being U.L. listed or approved which conveys to the consumer the impression that the product going into his home has been checked by U.L. That would be true, however, only in instances in which the cellulose bore the official U.L. label.

In one instance disclosed by the Subcommittee, a major cellulose manufacturer, Cellin Manufacturing Inc. of Lorton, Virginia, owned by Washington Gas Light Company claimed on its bags that its product was "Underwriters Laboratories Listed" although Cellin literally did not produce a single bag of UL labeled, or checked, product through all of 1977.<sup>8</sup>

Although not the "official" UL label, it is difficult to imagine a consumer being able to differentiate between the phrase "Underwriters Laboratories Listed" and the official UL label which includes the results of various UL tests.

Of 43 cellulose insulation manufacturers that were listed by U.L. in 1977 as participating in its fire classification program, 25 or 60% did not label a single bag of production for that entire year although eligible to advertise their being U.L. listed.<sup>9</sup>

This flagrant misuse of the U.L. name was summarized in the following colloquy between Chairman Moss and Jack Bono, Vice President, Underwriters Laboratories:

Mr. Moss. It appears that you have two procedures—one to test a product to determine its fire classification. Is that correct?

Mr. Bono. That's correct.

Mr. Moss. And a person having tested, could in their advertising, not on the product bag itself, state: This product

<sup>5</sup> *Id.* at 332.

<sup>6</sup> Appendix XII prepared by Subcommittee Staff from information provided by UL.

<sup>7</sup> *Hearings, supra* note 6, Chapter I, at 282-88.

<sup>8</sup> *Id.* at 348-51.

<sup>9</sup> *Id.* at 351. For complete listing of UL listed manufacturers who did label any product in 1977 see "Manufacturers Not Using Labels in 1977" as prepared by UL. (Appendix XIII)

is tested by Underwriters Laboratories and given classification such and such?

Mr. Bono. That's correct.

Mr. Moss. They could do that for how long after the test?

Mr. Bono. For two years.

Mr. Moss. They wouldn't have to produce a product in their production line that even met the test. All they would have to have done was submit a product to you, which you tested in your Laboratories, and determined that that product—that that particular mix that was tested—received a fire classification from Underwriters Laboratories.

Mr. Bono. I would agree with that statement, Congressman, with the additional qualification that in the testing, the sample would be selected by an Underwriters Laboratories representative at the factory, rather than just submitted.

Mr. Moss. On a given day from a given batch? There are no batch markings on it. Where would he get it from—off the regular production run?

Mr. Bono. Exactly—right off the production run.

Mr. Moss. They would test it, but they would know when you were coming to pick up that test.

Mr. Bono. Correct.<sup>10</sup>

As matters now stand under the current U.L. test program, a manufacturer may therefore:

1. Subscribe to the U.L. fire classification program but not subscribe to the full range of U.L. tests for corrosion, thermal resistance and other properities and in so doing, convey the impression that the product has been fully checked by U.L.

2. Maintain a U.L. listing for two years without labeling a single bag for that entire period and without being checked by U.L.

3. Label the production from one plant and not the other in the case of manufacturers with more than one plant, again creating the impression that all production has been U.L. checked.

4. Label some, but not all of the production from a given plant to enable the manufacturer to change chemical formulations at will or to market products that fail to meet U.L. specifications while advertising his association with U.L. In the latter instance, although not permitted to put the U.L. lable on the substandard, and possibly hazardous products, the manufacturer is free, nonetheless, to market the failed product in full view so to speak of the U.L. inspector.<sup>11</sup>

Accordingly, the U.L. listing and labeling program to the extent that it permits cellulose manufacturers to advertise their participation in the U.L. testing program while free to label less than 100% of their production is inherently flawed and misleading. After listening to the testimony and conducting his own examination of the UL witnesses, Representative Gore observed in summary “. . . [T]he conclusion that I'm left with is that we cannot, in good conscience, tell consumers that the UL listing is any guarantee to go by in this field.”<sup>12</sup>

<sup>10</sup> *Hearings, supra* note 6, Chapter I, at 366.

<sup>11</sup> *Id.* at 363.

<sup>12</sup> *Id.* at 359.

The misleading use of the UL name as a marketing device by cellulose manufacturers is particularly unfortunate given the absence of mandatory standards for home insulation. Absent such standards, safety minded consumers, having been conditioned over the years to rely on UL, are being misled by their reliance on UL's reputation. UL's failure to adequately address the misuse of its testing program by cellulose manufacturers reflects poorly on an organization devoted to "testing for public safety."

## CHAPTER V

*Developing a New Standard*

The two agencies with primary responsibility for home insulation are the Department of Energy and the Consumer Product Safety Commission. The former by virtue of its efforts to persuade Americans to reinsulate their homes and the latter because of its mandate to protect consumers against unreasonable risk of injury from hazardous products.

The Consumer Product Safety Commission has been foot-dragging on the issue of setting standards for home insulation since the matter was first brought to its attention in late 1975 following a series of home fires in Denver that were attributed to cellulose insulation.<sup>1</sup> The CPSC regional office in Denver reported on the matter on February 20, 1976, in noting that:

The facts are quite clear. There will be a continuing problem with the cellulose insulation that is installed in homes as long as any operator determines what amount of flame retardant is adequate to prevent fires instead of a standard that regulates this amount of retardant and sets forth uniformity in the trade.<sup>2</sup>

Eight months later, the Metropolitan Denver District Attorney's office formerly petitioned the CPSC to set standards for home insulation. By statute, the CPSC has 120 days to grant or to deny the petition. The 120 day period expired without Commission action. However, on July 12, 1977, Cellutron Products Corporation, a Parsonsburg, Maryland, manufacturer of cellulose insulation, wrote the CPSC requesting a hearing on the question of whether standards should be developed for home insulation.<sup>3</sup> On July 28, 1977, the CPSC announced that a public meeting to review the Denver petition would be held on August 22.

The chronology of events suggested to some observers that the decision to proceed with a public hearing on the Denver petition resulted from the industry letter. Charlie Donaldson of the public interest Housing Research Group, charged "that the CPSC is more favorably inclined to grant hearings requested by industry than if requested by consumers or consumer advocates."<sup>4</sup> At the August 22 hearing, numerous industry officials concerned over the inability of the home insulation industry to police itself, and fearful as to the consequences of continued bad publicity concerning the safety of their product, joined consumer spokespersons in imploring the CPSC to set standards

<sup>1</sup> State of Colorado, Metropolitan Denver District Attorney's Consumer Office, Petition to the United States Consumer Product Safety Commission, "Hazards in Home Insulation," (Appendix XIV). (CPSC Petition CP 77-1, October 20, 1976.)

<sup>2</sup> Memorandum from Denver CPSC Field Office to Robert Halterman, Office of Product Defect and Identification, February 20, 1976.

<sup>3</sup> Letter to Chairman CPSC from Ronald S. Jones, President, Cellutron Insulation, July 12, 1977.

<sup>4</sup> Testimony of Charlie Donaldson, Housing Research Group, "Consumer Product Safety Commission—Oversight," Hearings before the Subcommittee on Oversight and Investigations and Consumer Protection and Finance of the Committee on Interstate and Foreign Commerce, House of Representatives, 95th Congress, 1st Session, September 27, 1977, p. 163.



home insulation.<sup>5</sup> On March 13, 1977, the CPSC, two years and one month following the report by the Denver regional office and one and one-half years after the filing of the Denver petition, initiated a formal proceeding requesting interested parties to develop a standard for cellulose insulation for consideration by the Commission,<sup>6</sup> a process that could take several years in terms of promulgating a final standard judging from the Commission's record in other areas.<sup>7</sup>

Dismayed and frustrated by the Commission's inability to address an obvious safety concern in an expeditious manner, Congressman Toby Moffett and Senator Wendell Ford have proposed legislation that would require the CPSC to adopt the existing GSA specifications for cellulose insulation within 120 days as an interim measure pending the development by the CPSC of more comprehensive safety standards. The Ford bill, S. 2401, passed the Senate on January 23, 1978.

As with the CPSC, officials within the Department of Energy were aware of many of the relevant safety concerns well before the April 20, 1977, announcement of the Administration's proposed National Energy Plan.<sup>8</sup> Yet, both the Administration and the Department of Energy have failed to initiate or propose measures to upgrade the safety and the quality of the insulation that they are urging upon the American people through hopes of a tax credit, appeals to patriotism and other exhortations.

Chairman Moss pointed out, for example, how as a member of the Ad Hoc Energy Committee last spring he had "protested very vigorously against the tax incentive being offered ahead of the development of standards and the ability of the government to assure people that there would be an adequate supply of insulation material that would be safe for their use." Yet, he noted, "there was a pressing need to grant a tax credit, a further inducement to overload a market already under supplied and virtually assure the use of inferior materials to meet the demands of that market."<sup>9</sup>

Representative Moffett, while favoring the tax credit for home insulation, similarly criticized the Department of Energy at the Subcommittee hearing for not being in the forefront of efforts to improve the safety of home insulation.<sup>10</sup>

Owing to the near indifference of the CPSC and the DOE to home insulation safety, the General Services Administration, as noted by Chairman Moss:

appears to be doing more in government to develop a standard [for insulation] and understand a problem than anyone else—even those who have primary responsibility."<sup>11</sup>

As the purchasing arm of the Federal Government, the GSA sets standards and specifications for goods purchased directly by the Fed-

<sup>5</sup> U.S. Product Safety Commission, Public Meeting on Home Insulation, August 22, 1977, testimony of Charles D. Mesigh, Society of International Cellulose Manufacturers, pp. 107-113, Greg Niblett, Cellutron Products Corporation, pp. 177-191. Joe Penka, Monotherm Insulation Systems, Inc., pp. 220-228.

<sup>6</sup> CPSC, "Cellulose Home Insulation," *Federal Register*, March 13, 1978, pp. 10427-10433. The Denver Petition requested the Commission to initiate standard development procedures for cellulose, fiber glass, and plastic foam/resin home insulation. The CPSC has yet to take action on fiber glass and foam insulation.

<sup>7</sup> It took the CPSC 1½ and 2¼ years, respectively, to set standards for architectural glass and swimming pool slides under the offeror process. A notice of proceeding for the development of standards via the offeror process was issued on the following dates for the following products: power lawn mowers 7/22/74; match books 9/7/74; television sets 2/28/75; public playground equipment 3/7/75; and aluminum wire 11/4/75. In none of these cases has a standard been published.

<sup>8</sup> See for example the January 1, 1977, previously cited ERDA report on cellulose insulation.

<sup>9</sup> *Hearings*, *supra* note 6, chapter I, at 317 and 319.

<sup>10</sup> *Id.* at 316.

<sup>11</sup> *Id.* at 477.

eral Government. This program encompasses 4,500 federal specifications and 1,500 standards.<sup>12</sup> Included are specifications for loose fill cellulose insulation (HH-I-515C), mineral fiber loose fill insulation (HH-I-1030), and mineral fiber blankets or batts (HH-I-521). Those and other GSA specifications apply only to goods and services purchased by the federal government and as such have no bearing on insulation purchased by consumers.

While the Federal Energy Administration and the CPSC slumbered, the GSA initiated efforts to upgrade its insulation specifications in 1976. On November 4, 1977, following a series of meetings with industry, the GSA issued its proposed new standards for insulation purchased by the federal government. Interested parties were given sixty days to comment.

The proposed new specifications on mineral fiber insulation included a new corrosion test, replacement of the Steiner tunnel test with a radiant panel test, the adoption of a smouldering test, and the requirement that fiber glass batts with paper vapor barriers be subjected to the radiant panel test paper side up.

The most far reaching changes proposed by the GSA were contained in its proposed HH-I-515D specifications for loose fill cellulose insulation. The new specifications included, for example, a requirement concerning fungal growth. As explained by the GSA:

With respect to the fungal growth on cellulose insulation, it is possible that this condition could cause the degrading of the thermal properties of the insulation by destroying the structure of the fibers. It could provide a source of fungal spores which might penetrate the living area and cause health problems. It could increase the corrosive action of the insulation material through the accumulation of metabolic products.<sup>13</sup>

Other proposed changes included a requirement that all cellulose tests be conducted at the product's settled density, i.e., "the density of the product that would be expected to be found in the field sometime after installation. . . ."<sup>14</sup> That requirement would eliminate the current practice of some cellulose manufacturers of having their product tested at an arbitrary density to enhance their chances of passing the corrosion test or to obtain a better fire safety test result.<sup>15</sup>

Of the several changes included in the proposed GSA D standard for cellulose, the most far reaching and controversial related to the proposal, based on recommendations from the National Bureau of Standards, the acknowledged fire safety experts within the Federal Government, to substitute use of a radiant panel test for the Steiner 25-foot tunnel test. The proposed new standard also included a smouldering test which is not included in the existing GSA specifications.

The smouldering test is designed to determine whether cellulose will continue to smoulder after the smouldering has progressed beyond the initial heat source, such as a hot electrical wire or a recessed light-

<sup>12</sup> *Id.* at 374. Federal specifications are technical descriptions of materials, products, or services. Federal standards establish engineering or technical limitations and applications for materials, processes, methods, and designs and are used primarily as references in specifications.

<sup>13</sup> *Hearings*, *supra* note 6, chapter 1, at 376-77.

<sup>14</sup> *Id.* at 376.

<sup>15</sup> *Id.* at 285-6.

ing fixture. Under the smouldering test proposed by the GSA, a lighted cigarette is inserted vertically, lit end up, into the center of a sample of insulation for two hours or until any smouldering has ceased. In order to pass the test, the sample must experience a weight loss of less than 15% and exhibit no evidence of flame or charring beyond approximately 7 inches from the cigarette.

In testimony before the Subcommittee, the GSA based its decision to switch to a radiant panel test and to adopt a smouldering test on the following:

1. The poor relationship between the Steiner tunnel and an actual attic situation.
2. The failure of the tunnel to address a small open flame or a smouldering ignition source.
3. The particular unsuitability of the tunnel test for low density materials, such as cellulose.
4. Fire data from the National Bureau of Standards showing that covered electrical, or heating devices, or wiring hot spot may cause ignition of exposed insulation, factors not simulated in the tunnel test.
5. The ability of the floor radiant panel test to better simulate the configuration and radiant heat exposure which may be experienced by insulation placed between attic floor joists and subjected to a small open flame ignition.<sup>16</sup>

There is general consensus among most knowledgeable persons within industry and government to the principle of a radiant panel and smouldering test. Reaction has ranged, however, from seeming non-concern to acute anxiety concerning the ability of industry to convert to the new test methods called for by the proposed GSA specifications. In the view of the Subcommittee, the issue of how many cellulose manufacturers can readily adapt to the proposed GSA specifications, should not be divorced from the issue of setting realistic safety standards for cellulose insulation. As noted by Charlie Donaldson of the Housing Research Group:

[T]he bottom line as far as I am concerned is that [the existing] 515C [specification] is simply not adequate to protect the consumer.<sup>17</sup>

Dr. Maxine Savitz, Director, Division of Buildings and Community Systems, Department of Energy, estimates that while 80% of the manufacturers can pass the existing GSA specifications that perhaps only 10 to 30% can pass the D version.<sup>18</sup> Savitz's view is not shared by Chuck Mesigh, President of the Society of International Cellulose Insulation Manufacturers, who produce 35% of the nation's cellulose insulation. According to Mesigh, six of seven SICIM members recently passed both the radiant panel and smouldering tests as performed by Certified Testing Laboratories of Dalton, Georgia. Moreover, Mesigh estimates that at least 80% of the 20 SICIM members could meet the D standard within a few months.<sup>19</sup>

L. A. Barron, Managing Director of the National Cellulose Insulation Manufacturing Association (NCIMA), a rival trade group repre-

<sup>16</sup> *Id.* at 375-6.

<sup>17</sup> Testimony of Charlie Donaldson, Amendments to the Consumer Product Safety Act, Subcommittee on Consumer Production and Finance of the Committee on Interstate and Foreign Commerce, House of Representatives, February 28, 1978, p. 37. (Hereafter cited as Hearing, February 28.)

<sup>18</sup> *Ibid.*, p. 95.

<sup>19</sup> *Ibid.*, p. 30.



senting 12 member companies that produce 30% of the total industry tonnage, considers enactment of the D standard premature on grounds that "the data base" for the proposed radiant panel and smouldering test "is just eleven tests."<sup>20</sup> The Subcommittee is at a loss to determine the basis of Mr. Barron's contention, an apparent widely circulated industry rumor at variance with the facts.

The National Bureau of Standards has run 12 radiant panel tests on cellulose as per the new GSA specification plus many more during the testing and development stage of the new specifications. Various independent testing laboratories have run an additional 69 radiant panel tests pursuant to the proposed D standard. The NBS has run 12 smouldering tests as specified in the proposed D version and 40 additional tests have been conducted by independent laboratories.

Of the 81 radiant panel tests conducted to date, 49 percent of the samples tested passed. Of the 52 smouldering tests, 36 percent of the samples passed.<sup>21</sup>

Those percentages do not provide a basis, however, for even guessing at the number of manufacturers who will be able to meet the new specifications and the amount of production that might be removed from the market should the D standard be applied to all cellulose insulation.

Tests conducted to date while providing clues as to the ability of cellulose manufacturers to meet the proposed GSA specification on the basis of current production are silent concerning the ability of manufacturers to meet the D specification through the use of additional fire retardants or a change in chemical formulations. If Mr. Mesigh of SICIM is correct in his view that 80% of the members of his organization can meet the new GSA specifications within a few months, one must assume that the overwhelming majority of the industry in terms of output, can adjust to the new specifications within a reasonable time frame. Those who cannot in nearly all cases would doubtlessly consist of those whose manufacturing process is so crude as to preclude their passing even the existing C standard on a consistent basis.

At this writing, the GSA has reviewed the comments submitted by industry and other interested parties relative to its three new proposed specifications for insulation. On March 23, the GSA released a slightly altered version of its proposed cellulose specifications for an additional two weeks of comment. The proposed specifications for mineral wool insulation will similarly be resubmitted for additional comments within the next month or two.

#### *Subcommittee Recommendations*

The Moffett bill, H.R. 10637, was developed prior to the issuance of the new proposed GSA specifications for loose fill cellulose insulation and prior to the March 1978 hearings of both this Subcommittee and the Subcommittee on Consumer Protection and Finance. In view of those developments, and with the general concurrence of Representative Moffett, the Subcommittee recommends that the Moffett bill be amended to reflect the record of the two Subcommittees and the work of the GSA.

The Moffett bill requires the Consumer Product Safety Commission to adopt within 120 days the existing GSA C standard for cellulose

<sup>20</sup> *Ibid.*, p. 95.

<sup>21</sup> General Services Administration, "Summary of Radiant Panel and Smouldering Tests Conducted in Accordance with Proposed HII-1-515 D." (March 23, 1978)



insulation as an interim emergency measure. It may not, however, require the CPSC to move beyond the C standard. Under that proposal, the industry, given the CPSC's track record, will be permitted to get by for several years on the basis of a totally inadequate standard.

The Subcommittee accordingly recommends that the CPSC be required, instead, to promulgate a D based standard for cellulose insulation within 90 days to become effective 120 days later.

The 90 day interval between passage of the Subcommittee recommended bill and the promulgation by the CPSC of a D based standard for cellulose insulation would permit the CPSC to make whatever technical adjustments and changes that may be required in the D standard.

While there is a significant volume of radiant panel test data, few of the tests have been run on identical materials by different laboratories. Similar questions have been raised regarding the smouldering test. To resolve those issues the NBS is conducting a round robin radiant panel and smouldering test using identical commercially available cellulose and involving nine laboratories—six independents and three from government. Six different materials will be tested three times each by each laboratory for a total of 162 test results.

The round robin test results should be available to the CPSC by the end of June for use in promulgating its D based standard. In the unlikely event that one or both of those test procedures is found to be nonreproducible, the CPSC could hold the radiant panel and/or the smouldering test in abeyance in promulgating its D based standard pending additional research.

#### SUPPLY IMPACT

The Subcommittee recommendation concerning a D based standard for cellulose insulation will have an uncertain impact on the availability of cellulose insulation in terms of manufacturers incapable or unwilling to upgrade the safety of their product and because of the resulting increased demands for boric acid.

Under the proposed D standard, an undetermined number of cellulose manufacturers, particularly those with a Class II product, may have to increase their use of boric acid by as much as 40% to pass the smouldering test.<sup>22</sup> The use of boric acid as a fire retardant in cellulose insulation typically ranges from five to ten percent of the total weight of the product. Other flame retardants and inorganic chemicals are used to bring the total chemical loading to 20 to 30% by weight of the finished product.<sup>23</sup>

Manufacturers who use sulfate, phosphate and other alternatives to boric acid may or may not be able to meet either the existing C or proposed D specification for cellulose insulation, particularly with regards to corrosion. But as the U.S. Department of Commerce notes, no definite information exists concerning:

1. The preferred chemical fire retardant composition for cellulosic insulation.

<sup>22</sup> Prepared Statement, John O'Leary, February 23. Memorandum of Subcommittee Staff Telephone Conversation with Robert Anderson of Diversified Insulation, March 7, 1978.

<sup>23</sup> U.S. Department of Commerce, Industry and Trade Administration, "Boric Acid 1978 U.S. Supply Situation," February 23, 1978, p. 6.

2. What chemical compounds can replace boric acid as a fire retardant.

3. The effect on requirements for boric acid given mandatory standards.<sup>24</sup>

For those reasons, one cannot even guess as to the impact of either a mandatory C or D based standard for cellulose insulation on the availability of boric acid. About all that can be said is that both standards, but particularly the D, will require additional use of boric acid.

At the present time, there is an oversupply of boric acid on the market due primarily to a tremendous fall off in cellulose sales. According to industry, demand for cellulose since January has dropped between 45 to 55% and as much as 80% in certain areas.<sup>25</sup> It is not known however, the extent to which that is due to harsh weather, adverse publicity concerning cellulose, or a general softening of the overall insulation market. Were the cellulose market to rebound this summer, shortages of boric acid could result from the inability of cellulose manufacturers to pay the higher prices prevailing for imported supplies.<sup>26</sup>

If forced to choose, however, between the adoption of a realistic standard for cellulose home insulation and a possible reduction in supply, the Subcommittee has no hesitation in putting fire safety ahead of supply.

The world is not going to run out of oil within the next year. Indeed, there is currently a glut of oil on the world market. We must conserve energy, but there is time to do so as far as insulation is concerned without jeopardizing the safety of millions of American homes. In the long term, from an energy savings perspective, it matters hardly whether we reinsulate four or ten million homes within the next year. Home reinsulation is but a relatively small portion of the overall strategy that we as a nation must pursue to obtain a reduction in oil imports by 1985 as called for by the Administration. A meaningful reduction in oil imports by 1985 is a goal that we as a nation can and will achieve. But in reaching that goal, we should not bow to the expediency of the moment by filling the walls and ceilings of millions of American homes with potentially dangerous ground up newspaper.

The Administration's goal of reinsulating 90% of existing homes by 1985 is laudable. But this effort should proceed in an orderly, sensible fashion and as such, calls for the adoption of meaningful standards for home insulation, particularly cellulose insulation as called for by the Subcommittee.

<sup>24</sup> *Ibid.*

<sup>25</sup> *Mesigh, Hearing, February 28*, note 17, at 74.

<sup>26</sup> Commerce Department. "U.S. Supply Situation," p. 18.

## CHAPTER VI

*Enforcement*

Under both the Moffett-Ford and Subcommittee proposals, the CPSC would have primary responsibility for enforcing the federal standard for cellulose insulation.<sup>1</sup> The Subcommittee proposal goes beyond Moffett-Ford, however, in requiring all manufacturers of loose fill cellulose insulation to subscribe to an independent, third party testing and follow-up program of the type currently offered by Underwriters Laboratories, U.S. Testing Company and others.

The requirement that cellulose manufacturers subscribe to an independent follow-up testing program would in no way lessen the responsibility of the manufacturer to meet the federal standard nor would it detract from the obligation of the CPSC to insure compliance with the standard. Under the Subcommittee's proposal, the independent testing laboratories, having tested the product initially and found it to meet the standard, would check for continued compliance through a series of unannounced on-site inspections and tests.

Such inspections would be conducted at a minimum of four times per month. During each inspection, the laboratory representative would review inhouse quality control records, determine whether the product currently being produced was the same as that which had been tested originally, and conduct a limited number of safety checks. The results of those tests and factory visits would be furnished the CPSC on a monthly basis for use in its enforcement programs.

Under this proposal, the testing laboratories would no longer authorize use of its label to show conformity with a standard. All production rather would be labeled by the manufacturer to show compliance with the federal standard. That in turn would eliminate the current misuse of the UL testing program as discussed in Chapter IV wherein cellulose manufacturers advertise their product as being UL listed or approved when in fact only a miniscule portion of their production is being checked by UL.

A requirement that all cellulose manufacturers subscribe to an independent testing and follow-up program is not unique. The California Energy Commission has proposed, for example, that all manufacturers of loose fill cellulose insulation produced or sold in California maintain a testing and follow-up service contract with a State Energy Commission approved testing organization.<sup>2</sup>

The concept of an independent, third party testing procedure has been endorsed, moreover, by FTC Chairman Michael Pertschuk, the Department of Energy, and the industry in general as reflected in the Record of the Subcommittee.

In view of the present and anticipated resources of the CPSC, it is highly unlikely that the CPSC would be able to mount more than a token enforcement program unless supplemented by an independent third party testing program. Given the existence of a nationwide system for private testing organizations, there is no need, moreover,

<sup>1</sup> To supplement CPSC enforcement measures the Subcommittee recommends that the Moffett-Ford bill be amended to specifically indicate that the sale of cellulose insulation which fails to meet the Federal standard constitutes an unfair trade practice under the Federal Trade Commission Act.

<sup>2</sup> Proposed California Energy Commission Insulation Quality Standard, Cellulose Fiber, Loose Fill, Thermal Insulation, March 3, 1978. (Appendix XV)



for the CPSC to hire scores of inspectors to inspect 500 or more cellulose manufacturing plants on a weekly basis to assure continued compliance with the federal standard.

According to a CPSC document, that agency anticipates an annual enforcement program of 185 factory inspections and the testing of 30 samples.<sup>3</sup> In a meeting with the Subcommittee staff, officials of the CPSC envisioned possibly expanding that program to include an average of one factory inspection per plant per year. An enforcement program of such limited scope is deficient on its face and would mock the federal standard. Were the CPSC inspector to discover that production on a given day did not meet the federal standard, it would be inequitable and infeasible for the CPSC to seek to invoke civil or criminal penalties on the basis of a single day's production given the sensitive nature of the cellulose manufacturing process. Again, assuming that the CPSC inspector determined a violation on his annual factory visit and that the CPSC was able to bring the manufacturer into compliance, such an action would be of little comfort to consumers who had installed the offending manufacturer's product in their home during the proceeding year.

In view of the inherently limited enforcement capabilities of the CPSC, the only viable enforcement strategy is one in which the CPSC focuses its enforcement activities on the basis of monthly reports filed by the independent testing laboratories.

Absent such a program, many of the same cellulose insulation manufacturers who have contributed so handsomely to that industry's poor reputation will be sorely tempted to try to beat the system by counting on the odds of their avoiding the CPSC's sporadic inspections and relying on that agency's overall shabby enforcement record as documented in two General Accounting Office reports.<sup>4</sup>

A failure on the part of the Congress to legislate an effective enforcement program for cellulose insulation is likely to leave consumers in a worse position than at present. Conscientious and capable cellulose manufacturers, who currently compete with manufacturers who use cheap chemicals or crude manufacturing processes, cannot be expected to maintain their standards in a market where safety and quality do not count.

Much of what little control that exists today in the cellulose industry, moreover, derives from the role played by outside testing laboratories. The establishment of a federal standard for cellulose insulation, unless adequately enforced, could create a situation in which purchasers could be lulled into believing that all cellulose is safe, a circumstance that could cause manufacturers to forego outside testing once it was determined that such test results are no longer a selling point.

The setting of a meaningful standard for cellulose insulation is but a part of the responsibility facing the Congress. Having agreed on a standard the Congress can do no less than to establish a meaningful enforcement program that utilizes independent, private sector testing resources to supplement the obviously limited ability of the CPSC to provide the American people with a reasonable assurance concerning the safety cellulose insulation.

<sup>3</sup> CPSC, Summary of Staff Resources for Implementation of Section 3 (Mandatory GSA Specification IIIH-1-515 C as an Interim Consumer Product Safety Rule of S. 2401).

<sup>4</sup> General Accounting Office "Better Enforcement of Safety Requirements Needed by the Consumer Product Safety Commission," July 26, 1976, and "The Consumer Product Safety Commission Has No Assurance that Product Defects are Being Reported and Corrected," February 14, 1978.



## ADDITIONAL VIEWS OF HON. JOHN E. MOSS

In offering these additional views, I wish to underscore my endorsement of the subcommittee's recommendations, especially as they relate to the prompt enactment of a Federal standard for cellulose insulation based on the General Services Administration's proposed D standard. I also fully concur with the subcommittee's recommendation concerning the use of private testing laboratories to supplement Federal enforcement of a cellulose safety standard.

The subcommittee's report calls upon the Congress to enact legislation requiring the Consumer Product Safety Commission (CPSC) to promulgate a D-based standard for cellulose insulation within 90 days to go into effect 120 days later.

In the interim, the CPSC would be required to adopt the existing GSA C standard. The need to advance to a D-based standard frame is amply documented by the record of the subcommittee. The lack of a smoldering test and the overly crude relationship between the Steiner tunnel test and an actual attic fire situation render the existing C standard inadequate as a basis for establishing meaningful safety standards for cellulose.

The setting of realistic safety standards for cellulose insulation is but part of our obligation to the estimated 2 million consumers a year who insulate their homes with cellulose. Unless effectively enforced, a cellulose insulation safety standard would be unfair to consumers and industry alike. The former by virtue of their looking to the standard as a guarantee of the safety of cellulose and the latter because of its recent attempt to restore public confidence in cellulose following the misconduct of certain of its members, as documented by the record of this subcommittee.

The Consumer Product Safety Commission will most likely be assigned the task of enforcing the cellulose insulation safety standard. Left to its own devices, however, the CPSC cannot realistically be expected to assure the safety of cellulose due to its limited enforcement resources and the nature of the cellulose manufacturing process, which unless carefully controlled and monitored, can lead to an uneven distribution of fire retardent chemicals from lot to lot and from bag to bag.

Accordingly, an effort on the part of the CPSC to assure compliance throughout a 500-plant industry, by means of some 300 factory inspections a year, is deficient on its face.

Short of assigning Federal inspectors to every plant, the only viable enforcement alternative is for the Congress to require all cellulose manufacturers to subscribe to an approved, independent third-party testing and followup program of the type offered by various commercial testing laboratories.

The knowledge that their product would be checked on a continuing basis by a federally approved, independent testing laboratory, coupled with the realization that all such test results would be furnished the CPSC, would instill a far higher level of compliance throughout the industry than would obtain from an enforcement program based on possibly one CPSC factory inspection per year.

Those who argue against requiring third-party testing and follow-up do so on three grounds:

1. The time and resources required to approve the testing laboratories and followup inspection programs.

2. The financial burden on small cellulose manufacturers.

3. The inequity of requiring manufacturers with sophisticated quality control programs to subscribe to a third-party testing program.

The record of the April 19, 1978, Oversight and Investigations and Consumer Protection and Finance Subcommittees Joint Hearing on Enforcement of a Cellulose Insulation Safety Standard places the above arguments in proper perspective.

In my 26 years in the Congress, I have learned that the bureaucracy, rather than arguing the merits of a proposal per se, is more inclined to oppose a measure by claiming that it would unduly burden an already overworked agency. Thus, I was not surprised to learn that the CPSC, while not opposed to third-party testing and followup, does not favor its adoption at this time because of the resources that would be required to approve such programs.

Although it may be a bit exaggerated to claim that such a program could be set up over a long weekend, it is nonetheless true that the business of approving testing laboratories and followup programs, is far less burdensome than has been suggested by the CPSC. The California Energy Commission, which is in the process of adopting a program similar to that recommended by the subcommittee, anticipates no great difficulty in setting up its approved third-party testing program as reflected in their testimony before the subcommittees.

The contention that mandatory third-party testing would place small cellulose manufacturers at a competitive disadvantage is difficult to accept. Underwriters Laboratories has testified that its followup program adds approximately 50 cents to the cost of the insulation required to insulate an average size attic. Officials of the California Energy Commission estimate the cost of that State's four-times-per-month third-party inspection service to be about \$10,000 per year, in noting that "the small manufacturer, in order to make a go of it, has to be grossing maybe \$.5 million in sales or more."

The notion that mandatory third-party testing would be unfair to manufacturers with sophisticated quality control and testing programs ignores the testimony of Charles Mesigh, president of the Society of International Cellulose Insulation Manufacturers, who stated that "it is my opinion that there is not a cellulose manufacturer who is capable of conducting ASTM C-739 testing. I do not think that they are in a position to claim to be a testing facility."

Third-party testing has already been accepted by some 165 cellulose manufacturers. The subcommittee's proposal to mandate third-party testing would impose nothing new, costly or radical on the cellulose industry and indeed has been endorsed by the leading cellulose trade associations. Without such a requirement, I am concerned that the Congress will discover in the relatively near future that it has not fulfilled its obligation to the homeowner in legislating such steps as are necessary to assure the safety and quality of cellulose insulation.

JOHN E. MOSS.

## SEPARATE VIEWS OF HONORABLE JAMES M. COLLINS

I agree totally with this report's finding that there is a need for a mandatory Federal standard for cellulose insulation. I disagree, however, on the report's recommendation that a system of third-party testing and followup should be legislatively mandated.

I do not disagree on the need for a standard, but I have some concern about the enforcing and administering agency which will be the Consumer Product Safety Commission, which has a truly abysmal record of failure in virtually all of its endeavors. I sense that the majority have similar feelings, and thus, they have opted for the third-party certification mechanism as a means of minimizing the known inadequacies of the CPSC. Having said that, it is now incumbent upon me to state why I object to the third-party certification and favor the standard.

First, in order for this type of approach to be implemented, the certifiers must be approved by the Federal Government, and the accomplishment of this task would require that criteria be established to insure that the potential certifiers have the necessary equipment and staffing to fulfill this function. This would be a time-consuming process, and there is a definite need for prompt action on this matter.

Second, this concept of third-party certification is in my mind premature in that I do not have sufficient information to assess the impact that such a program would have upon competition in the cellulose insulation industry.

Third, the law will specify the GSA standard, and CPSC's control over it will be minimized because the legislation prescribes the GSA standard.

Another point I feel compelled to raise about this whole issue of a standard for the cellulose industry, as these hearings on this subject make clear, is the fact that there does not now exist a test that will measure flame retardant retention. In other words, a product could be manufactured with the highest degree of care and quality and be flame retardant when produced. There is, however no test available to determine whether or not that product will continue to be flame retardant several years from now.

I believe that work should be vigorously undertaken to develop such a test. The two major concerns with respect to cellulose insulation are fire retardancy and corrosion. There are tests available to measure for corrosive properties but not for flame retardancy. If such a flame retardancy retention test is developed, it should be promptly incorporated into the standard.

I believe the overwhelming majority of cellulose insulation manufacturers truly desire to make a quality product that is safe for consumer use, and will welcome standards that drive out the fly-by-night type of operators who are seeking only to realize gain and take untoward advantage of consumers seeking to conserve energy and reduce their utility bills. I saw evidence of this type of operator during the course of these hearings, and I did not see any industry spokesmen rushing to their defense.

I also feel that I should comment on the actions of the administration with respect to this issue of insulation. The subcommittee report notes that the administration was encouraging people to insulate. Their tools of encouragement were the lure of tax credits and calls to patriotism. As the report further notes, however, the administration was "remiss in failing to initiate actions necessary to provide consumers with a reasonable level of assurance concerning the safety and quality of home insulation." I believe that "remiss" does not adequately describe my view of this failure which I would describe as dereliction of a clear duty. This is but further evidence of the fact that the National Energy Plan proposed by the administration last year was a plan promulgated without adequate consideration being given to its consequences.

JAMES M. COLLINS.



## APPENDIX 1



UNITED STATES DEPARTMENT OF COMMERCE  
National Bureau of Standards  
Washington, D.C. 20234

October 4, 1977

MEMORANDUM PROGRESS REPORT TO THE FILES

From: D. Gross, Chairman  
Task Force on Fire Safety of Insulation

Members: Bailey, Buchbinder, Davis, Evans, McCarter, Parker

1. Introduction

With the current increased use of insulation there is a corresponding increase in the number of questions about fire safety. This is due to occasional outbreaks of fire incidents in local areas plus a general nationwide concern for the consequences of fire if increasing quantities of insulation are applied in attics, walls, crawl spaces and particularly around heaters and electrical devices. This was accentuated at the August 22nd public meeting called by the Consumer Product Safety Commission in response to a petition from the Attorney General's Office of Denver regarding the potential fire hazards of certain types of insulation. At that meeting, there were many requests that the Consumer Products Safety Commission use existing Federal Specifications as a basis for nationwide mandatory or voluntary standards. Federal specifications for construction materials are generally used for (a) Government purchase of materials for use in Federal buildings and (b) use by others in private or in federally supported housing. Consideration is also being given to the use of Federal specifications for acceptance of insulation materials in the event of enactment of tax credit legislation. This is addressed in NBSIR 75-795. The position expressed by a number of speakers at the CPSC meeting encompassed the following thought: "If it's Government policy to conserve energy it should be Government policy to insure use of safe products." The basic thesis for fire safe use of insulation is that the addition of insulation should not increase the normal and expected level of fire risk to the resident.

The methods used to install and protect insulation are extremely important from the standpoint of fire. Good installation practice, e.g. as specified in the National Electrical Code, and the Standard for Installation of Heat-Producing Appliances, would provide physical separations between heat appliances, electrical fixtures, etc. and thermal insulation. From a realistic standpoint, however, it may be anticipated that batt, blanket and loose-fill insulation will be placed in contact with such appliances and fixtures, particularly with do-it-yourself and retrofit insulation projects in single family homes. An effort should be made to advise those involved with the design, manufacture, testing and regulation of electrical fixtures, appliances and wiring, of the need to consider the potential operation when enclosed by or covered with insulation.

## 2. Objective

The objective of the task force activities was to review three Federal specifications within a limited time frame and to examine the appropriateness of their requirements in terms of fire safety. Although limited to the three specifications, it is felt that the conclusions of this study should be applicable to other types of insulation used in a similar manner. The three specifications are:

HH-I-515C Insulation Thermal (Loose Fill for Pneumatic or Poured Application): Cellulosic Wood Fiber

HH-I-521E Insulation Blankets, Thermal (Mineral Fiber, for Ambient Temperatures)

HH-I-1030A Insulation, Thermal (Mineral Fiber, for Pneumatic or Poured Application)

## 3. Fire Statistics

Complete and reliable fire data on the contribution of insulation to fires is not available. There have been reports of local incidents in Denver, in Michigan, and in a few other locations. For example, the Departments of Public Safety and Public Health in Michigan have assembled data on fire incidents involving paper insulation as the first material ignited. There were 158 cases reported in 1975 and 1976 and 49 cases to date in 1977 and between 45 and 55 percent of all cases involved treated paper insulation.

On a nationwide basis fire data are collected in the FIDO system of the National Fire Protection Association and the NFIRS data system of the National Fire Prevention and Control Administration. These data are summarized in a memo report included as Appendix A. The NFIRS data total 496 incidents in two states.

These data files code the first material ignited only and not the materials which contribute to fire spread. When insulation was the first material ignited, its composition was generally cellulosic. Non-cellulosic materials did not appear to play a significant role.

The two most commonly cited ignition sources were "electrical equipment, including short circuits", and "Propane torches". These data illustrate the two most significant potential major fire scenarios for insulation: (a) a covered electrical (or heating) device or a wiring hot spot may cause smoldering ignition of insulation or ignition of a flammable vapor barrier; (b) open flame from a plumbers torch or match may cause ignition of exposed insulation in the attic, basement or crawl space.

## 4. Rationale and Problem Outline

It is clear that a need exists for a meaningful standardized fire test. It is also evident that the same test should be applicable to all types of insulation used for the same purpose.

Current specifications appear to lean strongly toward surface flame spread. The rationale for this is not completely clear but probably is based partly on the convenience of using the same standard ASTM E-84 Flame Spread Test used in most codes for interior finish, and partly because no standard test method has been developed for flaming and smoldering ignition even though ignition is always the first step in the chain of events leading to a major fire.

The fire properties of materials which determine its potential contribution to the start or spread of fire and which may ultimately result in life loss, injury or property damage are: (a) heat contribution, (b) ignitability (flaming or smoldering), (c) surface flame spread, (d) smoke, (e) toxic combustion products.

In general these properties are sensitive to density and to test configuration since they affect the air flow patterns and the overall heat transfer.

Thermal insulation comes in several types and forms: boards, blocks, sheets, blankets, batts, felts, loose fill, foamed in place or prefoamed sheets. Insulation may be fibrous, closed or open cell or in composite form to yield high thermal resistance. Thermal insulation may be used in many types of buildings. For this study we were concerned mainly with use in residential dwellings.

Insulation may be directly exposed to a potential fire source, for example between the ceiling joists or roof rafters in an attic, in crawl spaces, in basement and utility spaces, or as decorative insulation; it may be enclosed in stud wall spaces, floor/ceiling spaces or other wall or roof cavities, and typically not exposed to a potential fire; or it may be temporarily exposed, such as during construction or repair. Thermal insulation is also used as part of fire rated assemblies, e.g. roof or floor ceiling assemblies.

In terms of priorities, it appears from the fire statistics that smoldering ignition of insulation in the attic may be the most important potential hazard, followed by flame spread along the surface of attic insulation, and ignition plus flame spread along blanket insulation on the walls and ceilings in the basement area. The Task Group placed its primary emphasis on attic insulation.

## 5. Current Test Methods

### A. Steiner Tunnel Test, ASTM E-84

This test utilizes a prescribed wire screen to retain loose fill insulation, and steel rods to hold batts and blankets. The specimen is mounted in a ceiling configuration of a long narrow tunnel and exposed to flames at one end and a prescribed air flow. The testing laboratory may apply a "correction" to the test result in an effort to account for the presence

of the wire screen, but this is not now a written test requirement. A basic question arises in the use of this test method for insulation materials: Is the flame spread classification a reasonable comparison tool for all densities and material forms, so that a classification of 100 means the same for a dense solid wood as for a low density cellulosic insulation? Does a classification of 25 apply equally to such materials? The test has been shown to be invalid for some low density fire-retardant treated plastic foams in terms of measuring their contribution to fire growth. Its applicability to, and appropriateness for other low-density insulation materials may also be seriously questioned.

B. Floor Mounted ASTM E-84 Tunnel Test Developed by the Fire Research Section, Division of Building Research, Ottawa, Canada

This test is being considered for loose fill cellulosic insulation. It is now used for carpeting and other floor coverings and for plastic foams. No wire screen is needed. However, there is some question as to whether the 5,000 Btu per minute burner with 4 1/2 foot flame exposure and 240 fpm induced draft within a narrow tunnel apparatus is applicable to a reasonable fire scenario in the attic.

C. "Two Foot" Tunnel Test

This is not a standard test method but is referenced in ASTM C 739 and is intended to serve as a low cost screening or quality control test in order to examine the effects of high temperature and humidity conditioning on cellulosic loose fill insulation.

D. Noncombustibility Test, ASTM E-136

This is a go/no go test used in some building codes for defining the acceptability of materials for use in certain classes of buildings.

E. Loss on Ignition Test

This is a simple weighing test used for estimating organic content. In HH-I-1030A the exposure temperature is 800°F (427 °C), although temperatures as high as 1652°F (900°C) are more commonly used in other specifications.

6. NBS Laboratory Test Studies

For this series of tests, a number of insulation materials meeting the three Federal specifications of interest were obtained from Government and commercial sources. In addition, a few insulation materials which were not identified with any particular specification, were also obtained. The materials are listed in Table 1. This list was not intended to be extensive or complete. For a fairly extensive analysis of loose fill cellulosic insulation, see ERDA Report 77-23.



### A. Mock-up Tests

A mock-up of a home attic space, schematically shown in Figure 1, was constructed and used for trial and error testing of several possible fire scenarios. The major ones contemplated were: insulation on or around recessed light fixtures, electric wiring, and hot gas flue pipes. In a separate wall section mock-up, the hazards of glowing electrical connections were studied.

Table 2 lists results of tests in the attic mock-up involving recessed light fixtures and electric wiring. Maximum temperatures obtained on the attic fixtures are tabulated for cases in which a smoldering fire was not established in the insulation. For the tests that resulted in a fire the approximate temperature of the fixture at the time the smoldering fire was initiated is given.

From this series of tests, it was found that recessed light fixtures could produce a smoldering fire in cellulosic insulation. For the particular fixtures tested, this occurred in cases where a bulb over the rated wattage for the fixture was used, e.g. a 150 watt bulb in a fixture rated for 100 watts maximum. As presently available test data only includes the evaluation of three different light fixtures, it may also be possible to initiate a fire with certain light fixtures using the rated wattage bulb(s).

Fires were also initiated in tests of electrically overloaded plastic-jacketed wiring covered with thermal insulation. The results of calculations shown in Figure 2 reveal that under well insulated conditions a moderate (35% over wire rating) current overload should not produce a fire in cellulosic loose fill insulation. However, the same calculations reveal that a severe current overload (80 - 100% over wire rating) under well insulated conditions could initiate a smoldering fire. These conclusions were verified by experiments, the results of which are listed in Table 2. It should also be noted that in all tests the insulated plastic jacketed wire was operating at temperatures well above the recommended maximum temperature (140°F) established for its use in the National Electrical Code. The long term effects of this type of abuse on the electric wiring was not studied.

### B. Attic Floor Radiant Panel Test

The conditions of this test simulate the configuration and radiant heat exposure which may be experienced by insulation laid between attic floor joists, and subjected to a small open flame ignition.

The test provides a distributed radiant heat flux ranging from 0.11 W/cm<sup>2</sup> to 1.1 W/cm<sup>2</sup>. The lower value is equivalent to the energy radiated by a blackbody at 100°C (212°F) and is approximately equal to the solar irradiance at ground level in Southern portions of the U.S. Under solar exposure the temperature likely to be reached in attics, on the underside of the roof, during summer conditions in certain areas of the U.S., ranges up to 71°C (160°F), equivalent to a blackbody irradiance of 0.08 W/cm<sup>2</sup>.

The test is used to measure the heat flux (or distance) at which the insulation will no longer propagate flame under the test conditions. This is called the critical radiant flux and is a quantitative measure of the ease with which flame propagation may occur on the surface of the test material in the given configuration.

The results with the Radiant Panel Test are summarized in Table 3 and shown in bar chart form in Figure 3. Clearly there is a wide range in test results ranging from no ignition and no flame propagation to flame propagation extending the full length of the one meter long specimen. In between there is a gradation in the measured flame travel distances and for five typical cellulosic loose fill insulations. The values ranged from 49 to 100 cm. These distances correspond to 0.34 and 0.11  $\text{W/cm}^2$ , respectively.

To check the reproducibility of the test method, SWRI at our request ran two selected samples of cellulosic insulation in their apparatus, following the recommended procedure. Their results were within 5% of the NBS values.

In order to provide a reasonable assurance that flames will not propagate extensively in attics likely to experience elevated temperatures, a critical radiant flux level of 0.12  $\text{W/cm}^2$  appears justified. The test method is described in detail in Appendix B. This suggested criterion for use with the test is 50% above the irradiance which might be expected to be impinging on the insulation providing a safety factor, against flame spread.

### C. Smoldering Test

The basic criterion was to devise a test method which would (a) provide a reliable index of smolder tendency and permit ratings of all types of (loose fill) insulation over a wide spectrum, (b) involve a minimum addition of equipment, and (c) be simple and expeditious so that it could be performed by unskilled or semi-skilled personnel.

#### 1. Cigarette Ignition Source

Using one cigarette placed on top of cellulose loose fill insulation or two cigarettes - one on top and one embedded - inches below the surface - it was found that untreated cellulosic loose fill insulation smoldered and resulted in a significant weight loss (18 percent). One fire retardant treated cellulose loose fill material smoldered considerably more than the untreated paper, giving a weight loss of 41%.

Various test parameters were explored. The size of the metal box specimen holder, specimen packing density, and cigarette placement were found of influence. Positioning the cigarette vertically and burning downward was found advantageous, being a simpler procedure and yielding an adequately intense exposure with but a single cigarette. As used, the cigarette is a slowly moving heat source that beats the material under test at an

appropriately slow rate for the initiation of smolder. It is designed to reasonably simulate in effect anticipated smoldering ignition sources. It might be envisioned as a very small electrical heater of about 3 or 4 watts power with a surface area of about a sq. cm at a temperature of about 600°C.

The cigarette smoldering test is described in detail in Appendix C. Test results are summarized in Table 4.

## 2. Heated Disk Source

Various trials were conducted using a small (2"D) disk heater (asbestos cement face) with attached fine wire thermocouple, on or within cellulosic loose fill insulation. Onset of a smoldering reaction was assumed synonymous with the first evidence of exothermicity and in this work occurred consistently in the vicinity of 330°C, irrespective of the cellulosic tested and of the heating rate, over a range of heating durations from minutes up to several hours. The disk heater darkened with use and posed problems in standardization as an ignition source.

## 3. Hot Plate Source

Trials were conducted with cellulosic loose fill insulation samples placed on hot plates (both steel faced and glass ceramic faced) with thermocouples centrally placed on the hot plate surface. Again, the inception of smoldering was consistently indicated to be near 330°C. This configuration proved unpromising for test purposes. Loose fill insulation heated in open-top boxes, at 2" and 4" depths, appeared to be self-smothering, with only modest propagation of smolder and little differentiation in the results between smolder-prone and smolder-reluctant cellulose. Other trials were conducted with the fill confined in a 4 in. diameter cylinder of window-type, galvanized iron screening with ready access of air. Again, there was little differentiation in results. It appeared that upward heat transfer was so effective that any ignited cellulosic would smolder completely, with power to the hot plate turned off at the time of ignition.

## D. Ignitability

A few initial tests were made using a timed burning tablet, or methenamine "pill", applied to an insulation sample at slightly elevated temperature (45°C/113°F). Of the materials tested two loose fill cellulosic materials permitted burning and/or smoldering to the edge of the container.

A test for ease of ignition of interior finish materials subjected to a steady wide area flame contact has been developed at NBS. Two 5.5 x 6 inch vertical specimens face each other at a distance of 2 inches apart. A steady methane diffusion flame passes up between the surfaces of the two specimens and produces an average incident heat flux of 3.2 W/cm<sup>2</sup>. The increase in flame radiation produced when either of the specimens begin to produce fuel is picked up by a phototube whose photo current is registered on a strip chart recorder. The ignitability of the material

is specified as the time at which its fuel contribution becomes significant. Observations of flame attachment to the specimen surface are also made during the test. However, in many instances these are small flamelets which do not contribute a significant amount of fuel.

This test was applied to the mineral fiber blankets which could be used exposed in a vertical orientation and the results are shown in Table 5. The unfaced insulation exhibited no flame attachment or significant fuel contribution. The kraft paper ignited rapidly and exhibited intense flaming for a few seconds. The foil facing deteriorated under the action of the exposure flame and the burning of the adhesive led to a very limited amount of flaming and an insignificant fuel contribution. These differences between the unfaced, foil faced, and kraft faced fiber glass blankets are consistent with the data on the heat release rate calorimeter where the peak heat release rates at an incident heat flux of  $6 \text{ W/cm}^2$  were 1.5, 6.5, and  $19 \text{ W/cm}^2$  respectively.

An ignition test more suited for the exposed loose fill insulation in a typical configuration between ceiling joists in the attic space is one being developed by a Working Group in the Fire Test Committee of the International Standards Organization. It employs a radiant heater to expose a horizontal specimen to incident radiant fluxes from 1 to  $5 \text{ W/cm}^2$ . A small pilot flame one inch above the center of the 8 inch diameter exposed area of the specimen is used to ignite the combustible pyrolysis products. The ignitability of the material is defined as the time at which flame starts to spread across the specimen. All of the materials examined in this study were tested and the results are shown in Table 6 for 1, 2, and  $5 \text{ W/cm}^2$  incident radiant flux.

The results indicate that all of the loose fill insulation materials ignite more readily than the fiber glass blankets. At  $1 \text{ W/cm}^2$ , ignition was attained only in the loose fill cellulosic insulation. Comparing materials C3, C4, and C5, the retardant treatment served to cause some delay in the time to ignition but not to prevent it. Some of the other materials had substantially shorter ignition times than the untreated material. These shorter times may be due to the nature of the basic cellulosic material as much as to the fire-retardant additives.

The ISO ignitability test operated at a flux level of  $1 \text{ W/cm}^2$  provides a significant distinction between the loose fill insulation materials. However, this distinction has not yet been related to the performance of the materials in a full scale fire simulation. This irradiance level is one that would be expected to occur only after a considerable fire buildup in the space in which the material would be exposed in the event of a real fire.

#### E. Heat Release

In the potential heat test, the total heat released during exposure of a specimen to a temperature of  $750^\circ\text{C}$  for 2 hours in air is measured. This



is accomplished by measuring the heat of combustion of the material in a standard oxygen bomb calorimeter and subtracting from this the heat of combustion of the residue remaining after exposure to the simulated standard fire.

In the heat release rate test, a specimen is exposed to a controlled level of radiant heat (typically  $6 \text{ W/cm}^2$ ) and the rate and total heat release is measured. Test results are given in Table 7. The peak values ranged from 1 to  $2 \text{ W/cm}^2$  for ceramic, mineral wool and glass fiber insulation and in the range of 15 to  $22 \text{ W/cm}^2$  for various paper products in sheet or loose fill form.

## 7. Future Work

A number of unresolved points need further work before a complete set of recommended changes or additions can be made covering fire safety and durability requirements in the present specifications. These include: a) large scale verification of the laboratory attic floor radiant panel test results using a simulated attic with thermal radiation and temperature levels corresponding to anticipated attic conditions, (b) validity of the range and method of temperature/humidity cycling to measure leaching of the water-soluble fire retardant chemicals in cellulose loose fill insulation (flame resistance permanency), (c) durability, aging and moisture resistance, (d) corrosiveness, (e) smoke and combustion products. In addition, further work appears desirable to define the effect of slight changes in density and to compare blown vs poured insulation applied by both professional and "do-it-yourself" operators.

Future recommendations may be needed to cover heat release, ignitability and smoke generation characteristics.

## 8. Interim Recommendations

1. Insulation intended for use in residential applications should be tested and rated for those properties which measure its tendency to be a principal contributor to fire. As a minimum, insulation intended for use in attics should be tested for tendency to ignite and smolder, and tendency to propagate open flaming.

2. The complete insulation assembly should be tested in the form in which it is intended to be used or in which it may reasonably be expected to be used. In particular it is recommended that HH-I-521E be revised to remove the current exclusion on testing of the membrane covering on the insulation blanket.

3. Federal specifications for the three types of materials should be revised to incorporate more appropriate heat and flame exposure tests. For the three particular specifications under discussion, the recommended test methods and proposed limits which can be recommended at this time are given as follows:

- A. Attic Floor Radiant Panel Test:      Critical Radiant Flux  $\geq 0.12 \text{ W/cm}^2$
- B. Smoldering Combustion Test:
- a. Weight loss  $< 15$  percent of initial weight
  - b. No charring within 4 cm of sides of specimen holder
  - c. No evidence of flaming combustion
4. All insulation should be labeled to indicate (a) conformance with the specifications and (b) cautions about fire dangers if applied improperly.

Table 1. Test Materials

Designation	Description	Label Information	
		Specification	ASTM E-84
G-1	Glass fiber blanket, unfaced R-19, 6 in. thick	HH-I-521E Type I	
G-2	Glass fiber blanket, foil faced R-11, 3.5 in. thick	HH-I-521E Type III	
G-3	Glass fiber blanket, unfaced "friction fit", 3.5 in thick	HH-I-521E Type I	FSC 20 SD 15 FC 20
G-4	Glass fiber pouring wool		
G-5	Glass fiber blanket Kraft paper faced R-30, 9 in thick	HH-I-521E Type II	
M-1	Mineral wool, high density pouring wool, min. density 1.9 lb/ft <sup>2</sup>	HH-I-1030A Type I	
P-1	Isocyanurate foam		FSC 25
P-2	Polystyrene foam		
P-3	Polyurethane foam		FSC 30
P-4	Polyurethane foam		
C-1	Cellulosic loose fill, FR		
C-2	Cellulosic loose fill, FR, density 2.2 lb/ft <sup>3</sup> , R factor 3.7/in	HH-I-515C	
C-3	Cellulosic loose fill, FR		FSC 35
C-4	Cellulosic loose fill, same as above but 0.5% less FR		FSC 37
C-5	Cellulosic loose fill, untreated		
C-6	Cellulosic loose fill, FR, density 2.1 lb/ft <sup>3</sup> R factor 3.8/in	HH-I-515B	FSC 25 SD 0 FC 25
C-7	Cellulosic loose fill, FR, density 2.5 lb/ft <sup>3</sup> R factor 5.0/in	HH-I-515B	
C-8	Cellulosic loose fill, FR, density 2.1 lb/ft <sup>3</sup> R factor 3.7/in	HH-I-515C	FSC 25 SD 0 FC 25
C-9	Cellulosic loose fill, FR,		
C-10	Cellulosic loose fill, untreated		

Table 2. Attic Mock-up Test Results

## Recessed Light Fixtures

Insulation Designation	Light Fixture	Bulb	Test Time	Fire	Maximum Temperature	Temperature Smoldering Initiated
C-4, R=35	Round-faced Reflector Spot, no cover plate	150w reflector	7 hr.	No	110°C	--
C-4, R=35		150w incandescent	4 hr.	No	140°C	--
C-6, R=34	100w square faced fixture with glass cover plate	100w incandescent	5 hr.	No	210°C	
C-6, R=34		150w incandescent	2.5 hr.	Yes	--	250°C
C-6, R=45		100w incandescent	5.5 hr.	No	216°C	
C-7, R=35		100w incandescent	5 hr.	No	208°C	
C-7, R=35		150w incandescent	3 hr.	Yes	--	250°C
C-7, R=35	150w square fixture with glass cover plate	150w incandescent	6.5 hr.	No	216°C	--

## Electrical Wiring Tests

Insulation Designation	Type	Current	Test Time	Fire	Maximum Temperature	Temperature Smoldering Initiated
R=33 sandwich C-2/wire/C-3/C3	#14 2 conductor and ground Plastic jacketed cable	25a	3 hr.	No	125°C	--
Same C-7, R=60*		29a	6 hr.	No	160°C	--
wire 6" above floor		29.5a	3.5 hr.	Yes	--	245°C
Same		25a	7 hr.	No	185°C	
Same		28a	7 hr.	Yes	--	240°C

\*Only one of the three joist spaces was insulated.



Table 3  
Attic Floor Radiant Panel Test

Insulation Type	Density, lb/ft <sup>3</sup>	Distance burned, cm.	Critical Radiant flux, W/cm <sup>2</sup>	Remarks
<u>Glass Fiber</u>				
G-1	0.86	0	>1.0	DNI (1)
G-2	0.72	0	>1.0	DNI - foil face up
G-3	0.74	0	>1.0	DNI
G-4	1.75	0	>1.0	DNI
G-5	0.78	100	<0.1	Paper face up
<u>Mineral Wool</u>				
M-1	2.98	0	>1.0	DNI
<u>Cellular Plastic</u>				
P-1	2.11	0	>1.0	DNI
P-2	1.87	0	>1.0	DNI, melted away from pilot flame
P-3	2.30	48	0.35	
P-4	1.77	54	0.27	
<u>Cellulosic Loose-fill</u>				
C-1	3.52 - 5.63	57	0.24	Tamped down to high density
C-1	7.35	57	0.24	Conditioned 22 hrs at 70°F and 65% r.h.
C-1	2.44	58	0.23	Dried 27 hrs at 180°F
C-1	3.76	66.5	0.18	
C-2	4.25 - 4.66	60	0.22	
C-2	3.55 - 4.07	57	0.24	Dried 24 hrs at 180°F
C-3	3.18	80	0.13	
C-4	3.18	83	0.12	
C-5	2.88	100	<0.1	
C-6	2.24 - 2.28	95	<0.11	
C-6	2.53	100	<0.1	Blown in by machine
C-7	2.11 - 4.39	100	<0.1	
C-9	---	49	0.34	

(1) DNI - did not ignite

Table 4. Results - Smolder Test\*

Material	Sample wt., g	Residue wt., g	Weight loss %	Closest char to wall, cm
Cellulosic loose fill				
C-1	147.0	109.3	26	1.0
	147.0	120.1	18	1.5
	147.0	111.4	24	1.5
C-2	147.0	145.4	1	(9)**
	156.2	155.0	1	(9)
C-3	142.0	48.1	66	0.5
	139.2	57.3	59	0.5
C-5	115.0	67.1	42	0.5
C-6	143.0	67.7	53	1.0
	143.0	65.4	54	1.0
C-7	148.0	51.2	65	0.0
	148.0	52.0	65	0.0
C-8	142.9	143.1	(+)	(9)
	145.0	143.2	(+)	(9)
C-9	148.0	94.0	36	0.0
	149.5	78.6	47	0.0
C-10	115.5	46.0	60	1.0
Glass fiber, paper faced				
G-5	69.4	69.7	(+)	(9)
Cellular polystyrene				
P-2	123.2	123.2	(0)	N.A.
Cellular polyurethane				
P-4	120.9	121.9	(+)	N.A.

\* 4 x 8 x 8 in box, temperature 21°C, relative humidity 65%

\*\* (9) no appreciable smolder

Table 5. Ease of Ignition Data on Glass Fiber Blanket

<u>Designation</u>	<u>Description</u>	<u>Flame Attachment*</u> (sec)	<u>Fuel Contribution**</u> (sec)
G-1	Type I (unfaced)	∞	∞
G-5	Type II (Kraft paper facing)		
	Paper toward flame	5	6
	Paper away from flame	∞	∞
G-2	Type III (foil faced)		
	Foil toward flame	14	∞
	Foil away from flame	∞	∞

\* Includes isolated flamelets anywhere on surface.

\*\* Requires 50% increase in output of flame photometer.

Table 6. Ignitability Test Results  
ISO Apparatus

<u>Materials</u>		<u>Times to Ignition (Sec)*</u>		
<u>Designation</u>	<u>Description</u>	<u>@ 1 W/cm<sup>2</sup></u>	<u>@ 2 W/cm<sup>2</sup></u>	<u>@ 5 W/cm<sup>2</sup></u>
C-5	Cellulose Loose Fill, untreated	127	12	1
C-3	Cellulose Loose Fill, FR	202	25	2
C-4	Cellulose Loose Fill, FR	237	18	3
C-1	Cellulose Loose Fill, FR	11	2	1
C-2	Cellulose Loose Fill, FR	243	15	1
C-7	Cellulose Loose Fill, FR	8	7	1
		17	6	2
C-6	Cellulose Loose Fill, FR	245	19	<1
G-1	Type I Unfaced	-	-	∞
G-5	Type II Kraft Faced			
	Kraft Exposed	∞	15	1
	Kraft Unexposed	-	-	∞
G-2	Type II Foil Faced			
	Foil Exposed	-	∞	35**
	Foil Unexposed	-	-	∞
M-1	Pouring Wool	-	-	∞

\*Average of 3 specimens

\*\*Ignition only occurred when the foil was punctured.



Table 7. Heat Release Data

6 W/cm<sup>2</sup> Flux, Horizontal Sample, 2-12/ Inch Thick

Designation	Description	Heat Release Data	
		Peak Rate W/cm <sup>2</sup>	10 Min. Total J/cm <sup>2</sup>
	Glass Fiber Blanket		
G-1	Unfaced, Type I	1.5	370
G-3	Friction Fit, Type I	1.2	100
G-5	Kraft Face, Type II		
	Kraft Up	19.0	1000
	Kraft Down	4.2	770
G-2	Foil Face, Type III		
	Foil Up	6.5	810
	Foil Down	5.6	1000
M-1	Pouring Wool	4.5	1300
	Cellulose Loose Fill		
C-5	Untreated	22.0	3300
C-3	FSR-35	15.0	2300
C-4	FSR-37	13.0	2500
C-1		10.0	2700
C-7		12.0	3000
C-2		17.0	3000
	Ceramic Fiber, Density 3 pcf	2.0	900

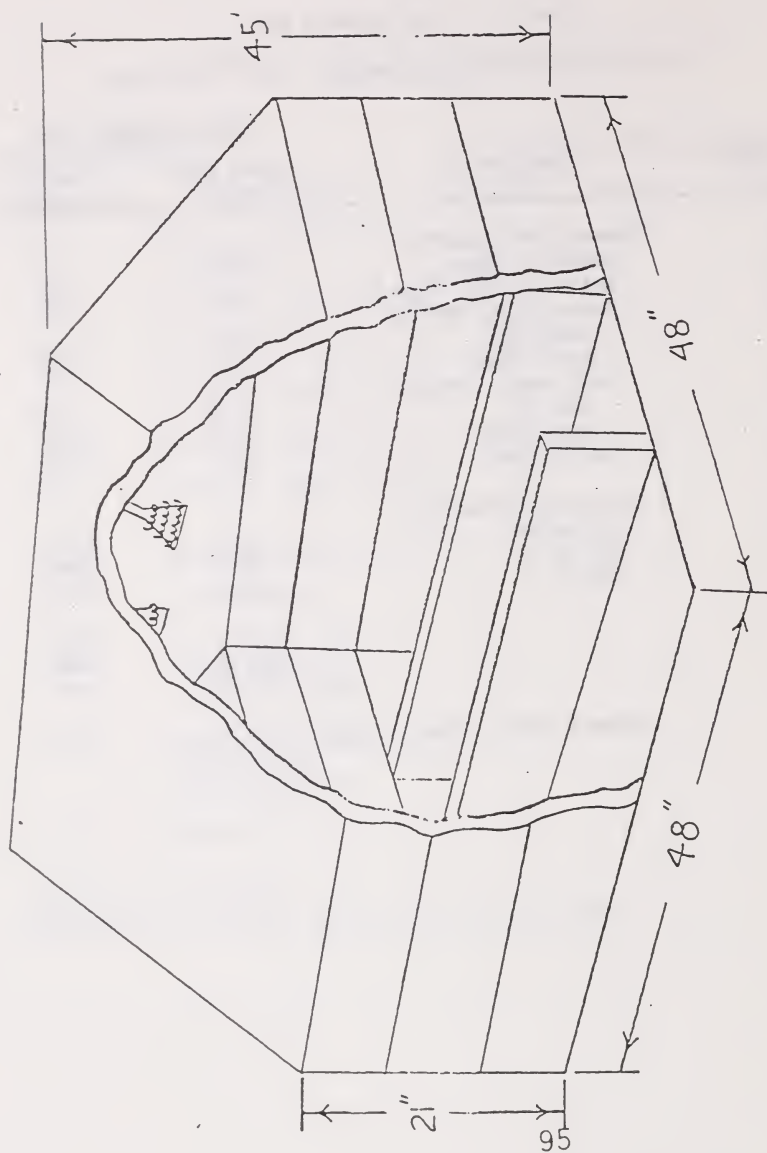
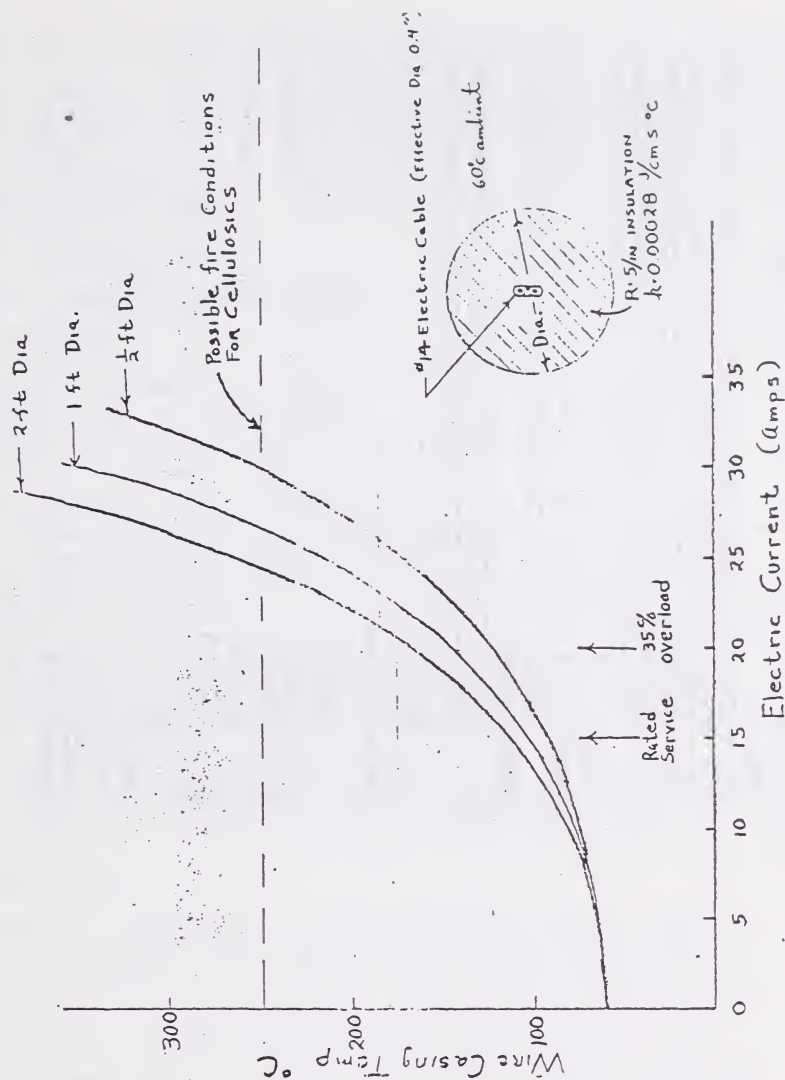


Fig. 1 Schematic Sketch of Mock-up Attic Space

FIG. 2 Calculation of Insulated #14 Wire Casing Temperature at Various Current



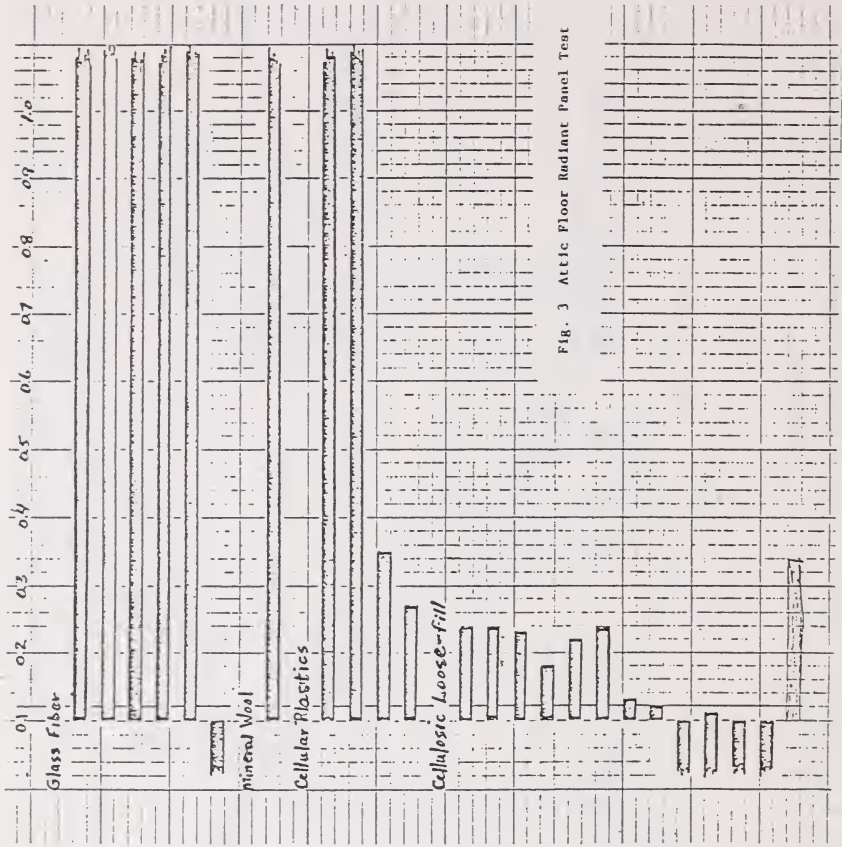


Fig. 3 Attic Floor Radiant Panel Test



August 24, 1977

MEMORANDUM FOR: D. Gross

From: B. Buchbinder

Subject: Analysis of Insulation Fire Data

## 1. Introduction

As part of the current insulation task force effort, we analyzed fire incident data for two primary reasons. First, to get some feeling for the magnitude of the current home insulation fire problem and second, to describe the typical scenarios for fires involving insulation.

There are the following limitations on what we can learn from the data:

1. Current data do not at all reflect the potential problems from retrofit of extra amounts of insulation in homes. This might bring flammable insulation closer to potential ignition sources, reduce available air for cooling of fixtures and wiring, etc.
2. The data bases available to us are the NFPCA National Fire Incident Reporting System (NFIRS) and the NFPA Field Incident Data Organization (FIDO). Both of these data bases identify only the first material ignited. We get no information on fires wherein insulation may play a significant role in fire growth, although another material is ignited first.
3. NFIRS is not yet national, and the data cover one year (1975) for California and five quarters (1976 and 1st quarter 1977) for Ohio.

## 2. Data Analysis

We received a listing of 496 incidents from NFIRS, and 28 incidents from FIDO. The NFIRS data covers all incidents reported in residential occupancies (NFPA 901 codes in 400 series of fixed property) where "thermal, acoustical insulation within wall, partition, or floor/ceiling space" (code 18 for form of material ignited) was the first material ignited (FMI). We received information on 28 incidents from FIDO, covering five years of reports on "serious fires". The FIDO system is heavily biased towards large loss or fatal fires. As we will see, fires involving insulation as the first material ignited appear to be much less serious in terms of personal injury, and especially so in terms of death.

We are planning to continue a "low key" effort to look at additional data sources, but for now, we can summarize the data as follows:

### 2.1 The magnitude of the problem

Table 1 summarizes a comparison of the NFIRS and FIDO insulation cases, with 2,741 upholstered furniture cases from the very same NFIRS data base (California and Ohio). The following points may be summarized from Table 1.

1. The incidence of upholstered furniture (UF) fires is more than five times that of insulation fires.
2. The death rate of .028 per reported UF fire is considerable; the rate for insulation fires is apparently very low (no deaths reported).
3. The injury rate for UF fires is 77% greater than for insulation fires.
4. The rate of fire spread beyond the room of origin, an indicator of fire severity, is 85% greater for UF fires than for insulation fires.

## 2.2 Typical insulation fire scenarios

The typical fires reported may best be described by looking at the composition of the insulation and the ignition source. Each of these factors is represented by two data elements in NFIRS. The material first ignited is described. In addition to the FMI, there is a data element entitled "type of material ignited (TMI)". The TMI for these insulation cases is tabulated in Table 2. We see that fiberboard is identified 18% of the time, with other cellulosic categories heavily represented. Note that the wood/paper total (code 69) should be added to the totals for the more specific categories such as 63, 65 and 67. We see that non-cellulosics play no significant role as the first material ignited.

The ignition source is defined by two data elements, "equipment involved in ignition" and "form of heat of ignition (FHI)". We show the distribution of the FHI code for our NFIRS cases in Table 3. It is apparent that this single data element tells the story. Short circuits, at 27%, is the single largest category. When combined with the remainder of the "heat from electrical equipment" category, the 20-29 group of codes accounts for 37% of the total.

"Torches and open flames" (codes 40-49) represent 23% of the cases. Within this category, torches alone total 82 cases (18%), with plumber's torches comprising 69 of these (15%). Some other subtotals of interest include 21 "electric lamp or bulb" cases (5%), 16 "properly operating electrical equipment" cases (3%), only 7 cases for matches, and 7 cases for lightning.

The 28 FIDO cases encompassed mobile property (mobile homes, travel trailers) in addition to the 400 code series for fixed property. Plumber's torches (13) and short circuits (9) were the only FHI codes to appear more than once. For TMI, 10 of the cases had either "fiberglass", "paper on fiberglass", or "paper on insulation" listed. Four cases listed fiberboard. There were only three other cases with TMI listed, two were "straw", one was "plastic".

In terms of occupancy, the FIDO cases showed the following:

Mobile homes	- 9
Apartments	- 6
Travel trailers	- 5
Single family dwellings	- 4
Hotel	- 1
Dormitory	- 1
Motor home	- 1
Recreational vehicle	- 1

Three of the FIDO cases involved very large loss, and these are not included in the average loss figures of Table 1.

Case 1: Hotel, propane plumber's torch, fiberboard insulation, started in ceiling assembly, property loss of \$2,500,000.

Case 2: Apartment, plumber's torch (leaky faucet), paper backing on fiberglass insulation, started in wall assembly off laundry room, property loss of \$200,000.

Case 3: Dormitory, propane plumber's torch, fiberboard insulation, started in wall assembly, property loss of \$134,000.

cc: Insulation Committee

Bailey  
Beansoliel  
Benjamin  
Davis  
Evans

Galowin  
Issen  
Levine  
Lyons  
Mathey

McCarter  
Parker  
Powell  
Rossiter  
Snell  
Trechs1

Table 1. Comparison Between NFIRS\* and FIDO Insulation Fires  
and NFIRS Upholstered Furniture Fires

	<u>Insulation Fires</u>		<u>Upholstered Furniture Fires</u>
	<u>NFIRS</u>	<u>FIDO</u>	<u>NFIRS**</u>
Number of incidents	496	28	2,741
Death rate, per reported fire	0	0	0.028
Injury rate, per reported fire	0.09	0	0.16
Average dollar loss:			
All cases	---	\$7,600	\$3,600
Those with injury	\$11,000	---	---
Those without injury	\$2,800	\$7,600	---
Proportion of cases with flame spread beyond room of origin	0.13	---	0.24

\*Strictly speaking, this is Ohio NFIRS and California CFIRS data combined, the latter furnished to NFPCA by the California State Fire Marshal's Office.

\*\*Only one and two family homes, and apartments are included here, whereas the insulation fires come from the entire 400 series of codes (all residential fixed property).



Table 2. Distribution of NFIRS Insulation Incidents,  
by Type of Material Ignited

<u>Form of Material</u>	<u>Codes</u>	<u>Cases</u>	
		<u>Number</u>	<u>Percentage</u>
Fiberboard	66	86	18
Wood	63, 65	72	15
Untreated paper	67	43	9
Fabric (man made fiber)	71	39	8
Wood/paper	69	37	8
Plastic	45, 49	26	5
Rubber	51	21	4
Treated paper	83	17	3
Other	--	60	12
Unclassified	--	90	18
Total		491	100

Table 3. Distribution of NFIRS Insulation Incidents  
by Form of Heat of Ignition

<u>Form of Heat of Ignition</u>	<u>Codes</u>	<u>Cases</u>	
		<u>Number</u>	<u>Percentage</u>
Short circuit	21-24	125	27
Torches and open flames	40-49	105	23
Sparks and heat from gas, liquid and solid fueled equipments	10-19	86	19
Heat from hot object	50-59	75	16
Heat from electrical equipment, <u>excluding</u> short circuits	20, 25-29	48	10
Other	---	24	5
Total		463	100

## APPENDIX B

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STANDARD METHOD OF TEST FOR CRITICAL  
RADIANT FLUX OF EXPOSED ATTIC  
FLOOR INSULATION USING A RADIANT  
HEAT ENERGY SOURCE

## 1. Scope

1.1 This method of test describes a procedure for measuring the critical radiant flux of exposed attic floor insulation subjected to a flaming ignition source in a graded radiant heat energy environment, in a test chamber. The test specimen may consist of loose-fill insulation, insulation batts, foam board insulation, or other form intended for the purpose.

1.2 This method measures the critical radiant flux at flame-out. It provides a basis for estimating one aspect of fire exposure behavior for attic floor insulation. The imposed radiant flux embraces the thermal radiation levels likely to impinge on the floor of an attic whose upper surfaces are heated by solar radiation and exposed to an open flame.

## 2. Summary of Method

2.1 The basic elements of the test chamber (Figure 1) are: 1) an air-gas fueled radiant heat energy panel inclined at 30° and directed at 2) a horizontally-mounted attic floor insulation specimen (Figure 2). The radiant panel generates a radiant energy flux distribution ranging along the 100-cm length of the test specimen from a nominal maximum of 1.0 watts/cm<sup>2</sup> to a minimum of 0.1 watts/cm<sup>2</sup>. The test is initiated by open flame ignition from a pilot burner. The distance burned to flame-out is converted to watts/cm<sup>2</sup> from the flux profile graph (Figure 8) and reported as critical radiant flux, watts/cm<sup>2</sup>.

## 3. Significance

3.1 This method of test is designed to provide a basis for estimating one aspect of the fire exposure behavior of an attic floor insulation in a building attic. The test environment is intended to simulate conditions that have been observed and defined in full-scale attic experiments.

3.2 The test is intended to be suitable for regulatory purposes, specification acceptance, design purposes, or development and research.

3.3 The fundamental assumption inherent in the test is that "critical radiant flux" is one measure of the sensitivity to flame spread of attic floor insulation installed in a building attic.

3.4 The test is applicable to attic floor insulation specimens installed by acceptable installation practice.

#### 4. Definition of Terms

4.1 Critical Radiant Flux is the level of incident radiant heat energy on the attic floor insulation system at the most distant flame-out point. It is reported as watts/cm<sup>2</sup> (Btu/ft<sup>2</sup> s).

4.2 Flux Profile is the curve relating incident radiant heat energy on the specimen plane to distance from the point of initiation of flaming ignition, i.e., 0 cm.

4.3 Total Flux Meter is the instrument used to measure the level of radiant heat energy incident on the specimen plane at any point.

4.4 Black Body Temperature is the temperature of a perfect radiator - a surface with an emissivity of unity and, therefore, a reflectivity of zero.

#### 5. Radiant Panel Test Chamber - Construction and Instrumentation

5.1 The radiant panel test chamber employed for this test shall be located in a draft-protected laboratory.

5.1.1 The radiant panel test chamber, Figures 3 and 4, shall consist of an enclosure 140 cm (55 in) long by 50 cm (19 1/2 in) deep by 71 cm (28 in) above the test specimen. The sides, ends and top shall be of 1.3 cm (1/2 in) calcium silicate board, such as Marinite XL, 0.58 g/cm<sup>3</sup> (36 lbs/ft<sup>3</sup>) nominal density, with a thermal conductivity @ 200 °F of 0.96 cal (g)/hr cm<sup>2</sup> deg C per cm [0.77 Btu/(hr) (ft<sup>2</sup>) (deg F per in)]. One side shall be provided with an approximately 10 cm x 110 cm (4 x 44 in) draft tight fire resistance glass window so that the entire length of the test specimen may be observed from outside the fire test chamber. On the same side and below the observation window is a door which, when open, allows the specimen platform to be moved out for mounting or removal of test specimens. A draft tight fire resistant observation window may be installed at the low flux end of the chamber.

5.1.2 The bottom of the test chamber shall consist of a sliding steel platform which has provisions for rigidly securing the test specimen holder in a fixed and level position. The free, or air access, area around the platform shall be in the range of 1950-3550 cm<sup>2</sup> (300-500 sq in).

5.1.3 The top of the chamber shall have an exhaust stack with interior dimensions of 12.5 cm (5 in) wide by 38 cm (15 in) deep by 30 cm (12 in) high at the opposite end of the chamber from the radiant energy source.

5.2 The radiant heat energy source shall be a panel of porous refractory material mounted in a cast iron frame, with a radiation surface of 30.5 x 45.7 cm (12 by 18 in). It shall be capable of operating at temperatures up to 816 °C (1500 °F). The panel fuel system shall consist of a venturi-type aspirator for mixing gas and air at approximately atmospheric pressure, a clean dry air supply capable of providing 28.3 NTP m<sup>3</sup> per hr (1000 Standard Cubic Feet per Hour) at 7.6 cm (3.0 in) of water, and suitable instrumentation for monitoring and controlling the flow of fuel to the panel.



5.2.1 The radiant heat energy panel is mounted in the chamber at 30° to the horizontal specimen plane. The horizontal distance from the 0 mark on the specimen fixture to the bottom edge (projected) of the radiating surface of the panel is 8.9 cm (3 1/2 in). The panel to specimen vertical distance is 14 cm (5 1/2 in) (see Figure 3). The angle and dimensions given above are critical in order to obtain the required radiant flux.

5.2.2 The radiation pyrometer for standardizing the thermal output of the panel shall be suitable for viewing a circular area 25.4 cm (10 in) in diameter at a range of about 1.37 m (54 in). It shall be calibrated over the black body temperature range of 490-510 °C (914-950 °F) in accordance with the procedure described in Appendix A.

5.2.3 A high impedance potentiometer voltmeter with a suitable millivolt range shall be used to monitor the output of the radiation pyrometer described in 5.2.2.

5.3 The dummy holder (see Figure 5), is constructed from heat-resistance stainless steel<sup>1</sup> having overall dimension of 115 cm (45 in) by 32 cm (12 3/4 in) with a specimen opening of 20 cm (7.9 in) x 100 cm (40 in). Six slots are cut in the flange on either side of the holder to reduce warping. The holder is fastened to the platform with two stud bolts at each end.

5.4 The specimen tray (see Figure 6) is constructed from heat-resistant stainless steel<sup>1</sup> having overall dimensions of 110 cm (43.3 in) by 27.3 cm (10.8 in); the depth of the tray is 5 cm (2 in). The flanges of the specimen tray are drilled to accommodate two stud bolts at each end; the bottom surface of the flange is 2.1 cm (0.83 in) below the top edge of the specimen tray.

5.5 The pilot burner, used to ignite the specimen, is a commercial propane venturi torch<sup>2</sup> with an axially symmetric burner tip having a propane supply tube with an orifice diameter of 0.0076 cm (0.003 in). In operation, the propane flow is adjusted to give a pencil flame blue inner cone length of 1.3 cm (1/2 in). The pilot burner is positioned so that the flame generated will impinge on the centerline of the specimen at the 0 distance burned point at right angles to the specimen length (see Figures 3 and 4). The burner shall be capable of being swung out of the ignition position so that the flame is horizontal and at least 5 cm (2 in) above the specimen plane.

5.6 Two 0.32 cm (1/8 in) stainless steel sheathed grounded junction chromel alumel thermocouples<sup>3</sup> are located in the Flooring Radiant Panel Test Chamber (see Figures 3 and 4). The chamber thermocouple is located in the longitudinal central vertical plane of the chamber 2.5 cm (1 in) down from the top and 10 cm (4 in) back from the inside of the exhaust stack. The exhaust stack thermocouple is centrally located 15.2 cm (6 in) from the top.

5.6.1 An indicating potentiometer with a range of 100-500 °C (212-932 °F) may be used to determine the chamber temperatures prior to a test.

<sup>1</sup>AISI Type 300 (UNA-N08330) or equivalent, thickness 0.198 cm (0.078 in).

<sup>2</sup>BERNZ-O-MATIC TX 101 or equivalent.

<sup>3</sup>Thermocouples should be kept clean to insure accuracy of readout.

5.7 An exhaust duct with a capacity of 28.3-85 NTP m<sup>3</sup> per minute (1000-3000 SCFM) decoupled from the chamber stack by at least 7.6 cm (3 in) on all sides and with an effective area of the canopy slightly larger than the plane area of the chamber with the specimen platform in the out position is used to remove combustion products from the chamber. With the panel turned on and the dummy specimen in place, there should be no measurable difference in air flow through the chamber stack with the exhaust on or off.

5.8 The dummy specimen which is used in the flux profile determination shall be made of 1.9 cm (3/4 in) inorganic 0.58 g/cm<sup>3</sup> (36 lbs/ft<sup>3</sup>) nominal density calcium silicate board, such as Marinite XL (see Figure 5). It is 25 cm (10 in) wide by 107 cm (42 in) long with 2.7 cm (1 1/16 in) diameter holes centered on and along the centerline at the 10, 20, 30, ..., 90 cm locations, measured from the maximum flux end of the specimen.

5.8.1 The total heat flux transducer used to determine the flux profile of the chamber in conjunction with the dummy specimen should be of the Schmidt-Boelter<sup>4</sup> type, have a range of 0-1.5 watts/cm<sup>2</sup> (0-1.32 Btu/ft<sup>2</sup> s), and shall be calibrated over the operating flux level range of 0.10 to 1.5 watts/cm<sup>2</sup> in accordance with the procedure outlined in Appendix A. A source of 15-25 °C cooling water shall be provided for this instrument.

5.8.2 A high impedance or potentiometric voltmeter with a range of 0-10 m.v. and reading to 0.01 m.v. shall be used to measure the output of the total heat flux transducer during the flux profile determination.

5.9 A timer shall be conveniently mounted on the chamber for measuring preheat and pilot contact time.

## 6. Safety Procedures

6.1 The possibility of a gas-air fuel explosion in the test chamber should be recognized. Suitable safeguards consistent with sound engineering practice should be installed in the panel fuel supply system. These may include one or more of the following: 1) a gas feed cut-off activated when the air supply fails, 2) a fire sensor directed at the panel surface that stops fuel flow when the panel flame goes out, 3) a commercial gas water heater or gas-fired furnace pilot burner control thermostatic shut-off which is activated when the gas supply fails or other suitable and approved device. Manual reset is a requirement of any safeguard system used.

6.2 In view of the potential hazard from products of combustion, the exhaust system must be so designed and operated that the laboratory environment is protected from smoke and gas. The operator should be instructed to minimize his exposure to combustion products by following sound safety practice, e.g., insure exhaust system is working properly, wear appropriate clothing including gloves, et al.

## 7. Sampling

7.1 The samples selected for testing shall be representative of the product.

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<sup>4</sup>Medtherm 64-2-20 will meet this requirement.

7.2 Standard ASTM sampling practice shall be followed where applicable, see ASTM Method E-122.

## 8. Test Specimens

8.1 The test specimen shall be attic floor insulation of sufficient size to fill the specimen tray to a depth of 5 cm (2 in).

8.2 Insofar as possible, the attic floor insulation specimen should simulate actual installation practice. Typical examples follow:

8.2.1 Loose-fill insulation blown in to fill the tray, then carefully screeded to provide a depth of 5 cm in the tray.

8.2.2 Loose-fill insulation poured in to fill the tray, then carefully screeded to provide a depth of 5 cm in the tray.

8.2.3 Insulation batts sliced to a depth of 5 cm and cut to fit into the tray.

8.2.4 Foam board insulation cut to fit into the tray to a depth of 5 cm.

8.3 A minimum of three specimens per sample shall be tested.

8.4 The density of the specimen tested shall be determined by weighing the specimen tray just prior to testing.

## 9. Radiant Heat Energy Flux Profile Standardization

9.1 In a continuing program of tests, the flux profile shall be determined not less than once a week. Where the time interval between tests is greater than one week, the flux profile shall be determined at the start of the test series.

9.2 Mount the dummy specimen in the mounting frame and attach the assembly to the sliding platform.

9.3 With the sliding platform out of the chamber, ignite the radiant panel. Allow the unit to heat for one hour. The pilot burner is off during this determination. Adjust the fuel mixture to give an air-rich flame. Make fuel flow settings to bring the panel to an apparent black body temperature as measured by the radiation pyrometer, of about 500 °C (932 °F), and the chamber temperature to about 180 °C (356 °F). When equilibrium has been established, move the specimen platform into the chamber.

9.4 Allow 0.5 hours for the closed chamber to equilibrate.

9.5 Measure the radiant heat energy flux level at the 40 cm point with the total flux meter instrumentation. This is done by inserting the flux meter in the opening so that its detecting plane is 0.16-0.32 cm (1/16-1/8 in) above and parallel to the plane of the dummy specimen and reading its output after 30 ± 10 seconds. If the level is within the limits specified in 9.6 the flux profile determination is started. If it is not, make the necessary adjustments in panel fuel flow. A suggested flux profile data log format is shown in Figure 7.

9.6 The test shall be run under chamber operating conditions which give a flux profile as shown in Figure 8. The radiant heat energy incident on the dummy specimen shall be between  $0.87$  and  $0.95 \text{ W/cm}^2$  ( $0.77$  and  $0.83 \text{ Btu/ft}^2 \text{ sec}$ ) at the  $20 \text{ cm}$  point, between  $0.48$  and  $0.52 \text{ W/cm}^2$  ( $0.42$  and  $0.46 \text{ Btu/ft}^2 \text{ sec}$ ) at the  $40 \text{ cm}$  point and between  $0.22$  and  $0.26 \text{ W/cm}^2$  ( $0.19$  and  $0.23 \text{ Btu/ft}^2 \text{ sec}$ ) at the  $60 \text{ cm}$  point.

9.7 Insert the flux meter in the  $10 \text{ cm}$  opening following the procedure given in 9.5 above. Read the m.v. output at  $30 \pm 10$  seconds and proceed to the  $20 \text{ cm}$  point. Repeat the  $10 \text{ cm}$  procedure. The  $30 - 90 \text{ cm}$  flux levels are determined in the same manner. Following the  $90 \text{ cm}$  measurement, make a check reading at  $40 \text{ cm}$ . If this is within the limits set forth in 9.6, the test chamber is in calibration and the profile determination is completed. If not, carefully adjust fuel flow, allow  $0.5$  hours for equilibrium and repeat the procedure.

9.8 Plot the radiant heat energy flux data as a function of distance along the specimen plane on rectangular coordinate graph paper. Carefully, draw the best smooth curve through the data points. This curve will hereafter be referred to as the flux profile curve.

9.9 Determine the open chamber apparent black body and chamber temperatures that are identified with the standard flux profile by opening the door and moving the specimen platform out. Allow  $0.5$  hours for the chamber to equilibrate. Read the radiation pyrometer output and record the apparent black body temperature in  $^{\circ}\text{C}$ . This is the temperature setting that can be used in subsequent test work in lieu of measuring the radiant flux at  $20 \text{ cm}$ ,  $40 \text{ cm}$ , and  $60 \text{ cm}$  using the dummy specimen. The chamber temperature also should be determined again after  $0.5$  hours and is an added check on operating conditions.

## 10. Conditioning

10.1 Test specimens are to be conditioned to equilibrium or a minimum of  $48$  hours, whichever is greater, at  $21 \pm 3 \text{ }^{\circ}\text{C}$  ( $69.8 \pm 5.4 \text{ }^{\circ}\text{F}$ ) and a relative humidity of  $50 \pm 5$  percent immediately prior to testing.

## 11. Test Procedure

11.1 With the sliding platform out of the chamber, ignite the radiant panel. Allow the unit to heat for one hour<sup>5</sup>. Read the panel apparent black body temperature and the chamber temperature. If these temperatures are in agreement to within  $\pm 5 \text{ }^{\circ}\text{C}$  with those determined in accordance with 9.9 above, the chamber is ready for use.

11.2 Mount the specimen tray on the sliding platform and position with stud bolts (see Figure 9).

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<sup>5</sup>It is recommended that a sheet of inorganic millboard be used to cover the opening when the hinged portion of the front panel is open and the specimen platform is moved out of the chamber. The millboard is used to prevent heating of the specimen and to protect the operator.



11.3 Ignite the pilot burner, move the specimen into the chamber, and close the door. Start the timer. After 2 minutes preheat, with the pilot burner on and set so that the flame is horizontal and 5 cm above the specimen, bring the pilot burner flame into contact with the center of the specimen at the 0 cm mark. Leave the pilot burner flame in contact with the specimen for 5 minutes, then remove to a position 5 cm above the specimen and leave burning until the test is terminated.

11.4 If the specimen does not ignite within 5 minutes following pilot burner flame application, the test is terminated by extinguishing the pilot burner flame. For specimens that do ignite, the test is continued until the flame goes out. Observe and record significant phenomena, such as discoloration, charring, smoldering, etc.

11.5 When the test is completed, the door is opened, the specimen platform is pulled out.

11.6 Measure the distance burned, i.e., the point of farthest advance of the flame front, to the nearest 0.1 cm. From the flux profile curve, convert the distance to  $\text{watts/cm}^2$  critical radiant heat flux at flame out. Read to two significant figures. A suggested data log format is shown in Figure 10.

11.7 Remove the specimen tray from the moveable platform.

11.8 The succeeding test can begin as soon as the panel apparent black body temperature and chamber temperature are verified (see 11.1). The specimen tray should be at room temperature prior to insertion of the next specimen.

## 12. Report

12.1 The report shall include the following:

12.1.1 Description of the attic floor insulation.

12.1.2 Description of the procedure used to prepare the floor insulation specimen.

12.1.3 Number of specimens tested, including critical radiant flux and density for each specimen as tested.

12.1.4 Observations of the burning characteristics of the specimen, such as discoloration, charring, smoldering, etc.

## APPENDIX A

## Procedure for Calibration of Radiation Instrumentation

## A1. Radiation Pyrometer

A1.1 Calibrate the radiation pyrometer by means of a conventional black body enclosure placed within a furnace and maintained at uniform temperatures of 490, 500, and 510 °C (914, 932, 950 °F). The black body enclosure may consist of a closed chromel metal cylinder with a small sight hole in one end. Sight the radiation pyrometer upon the opposite end of the cylinder where a thermocouple indicates the black body temperature. Place the thermocouple within a drilled hole and in good thermal contact with the black body. When the black body enclosure has reached the appropriate temperature equilibrium, read the output of the radiation pyrometer. Repeat for each temperature.

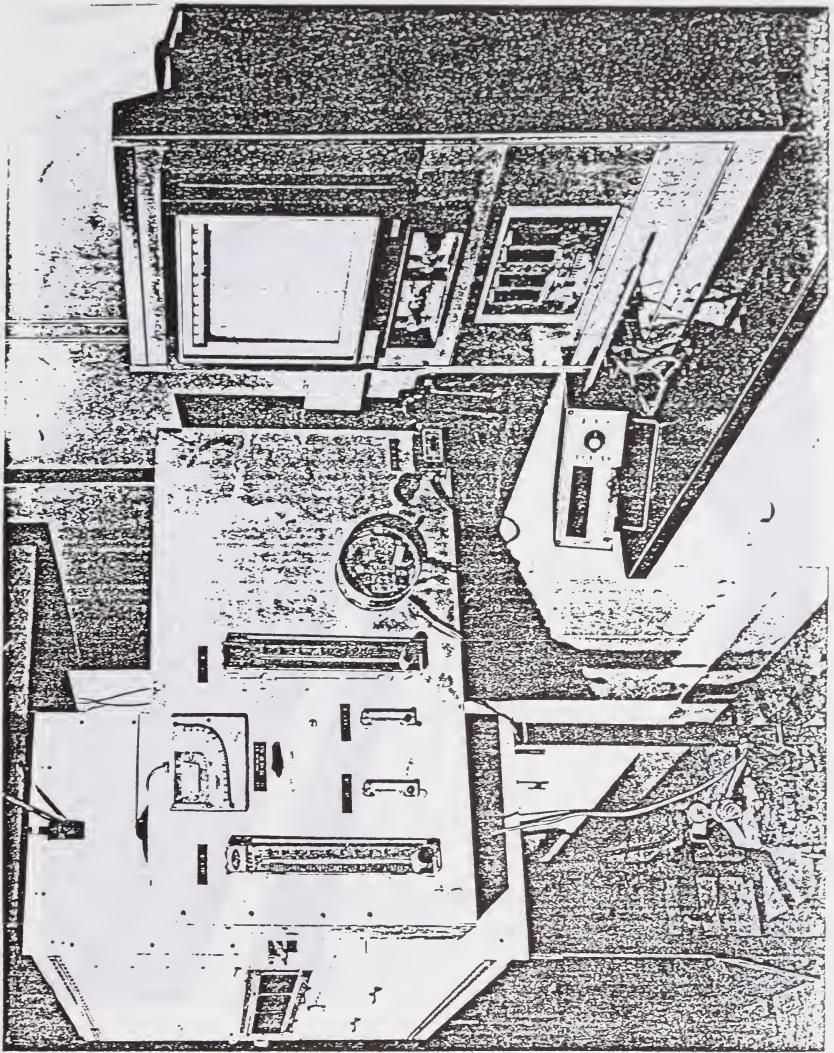
## A2. Total Heat Flux Meter

A2.1 The total flux meter shall be calibrated by the National Bureau of Standards<sup>1</sup>, or alternatively, its calibration shall be developed by transfer calibration methods with an NBS calibrated flux meter. This latter calibration shall make use of the radiant panel tester as the heat source. Measurements shall be made at each of the nine dummy specimen positions and the mean value of these results shall constitute the final calibration.

A2.2 It is recommended that each laboratory maintain a dedicated calibrated reference flux meter against which one or more working flux meters can be compared as needed. The working flux meters should be calibrated according to the procedure of A2.1 at least once per year.

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<sup>1</sup>Direct requests for such calibration services to the: Optical Radiation Section, 232.04, National Bureau of Standards, Washington, D.C. 20234.





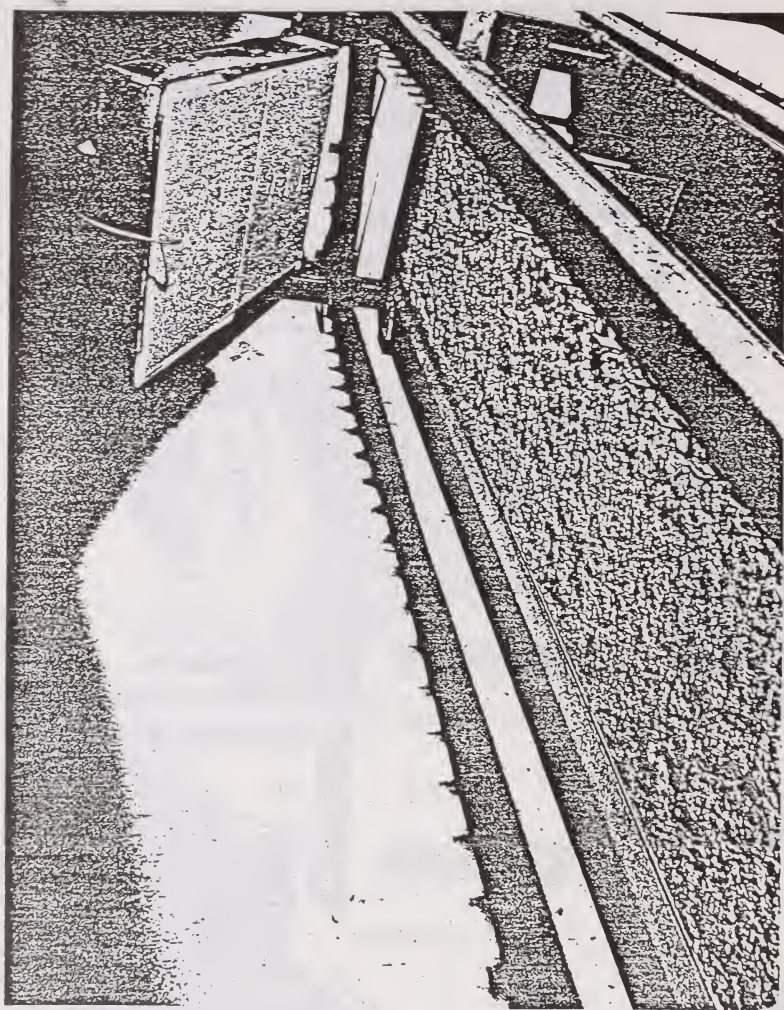
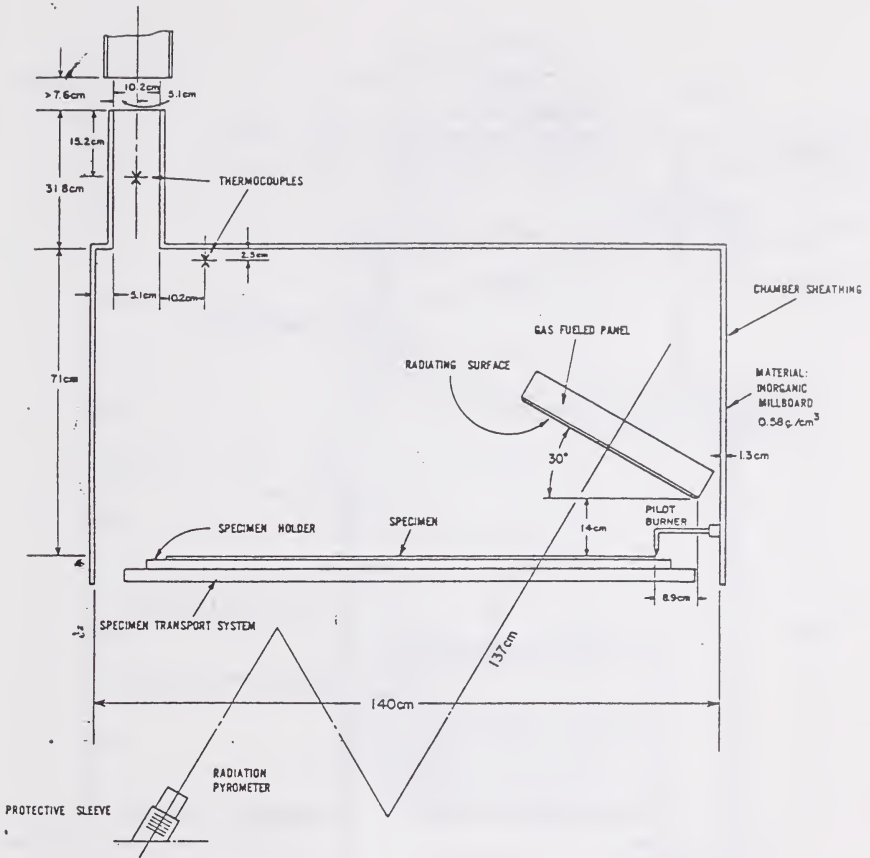


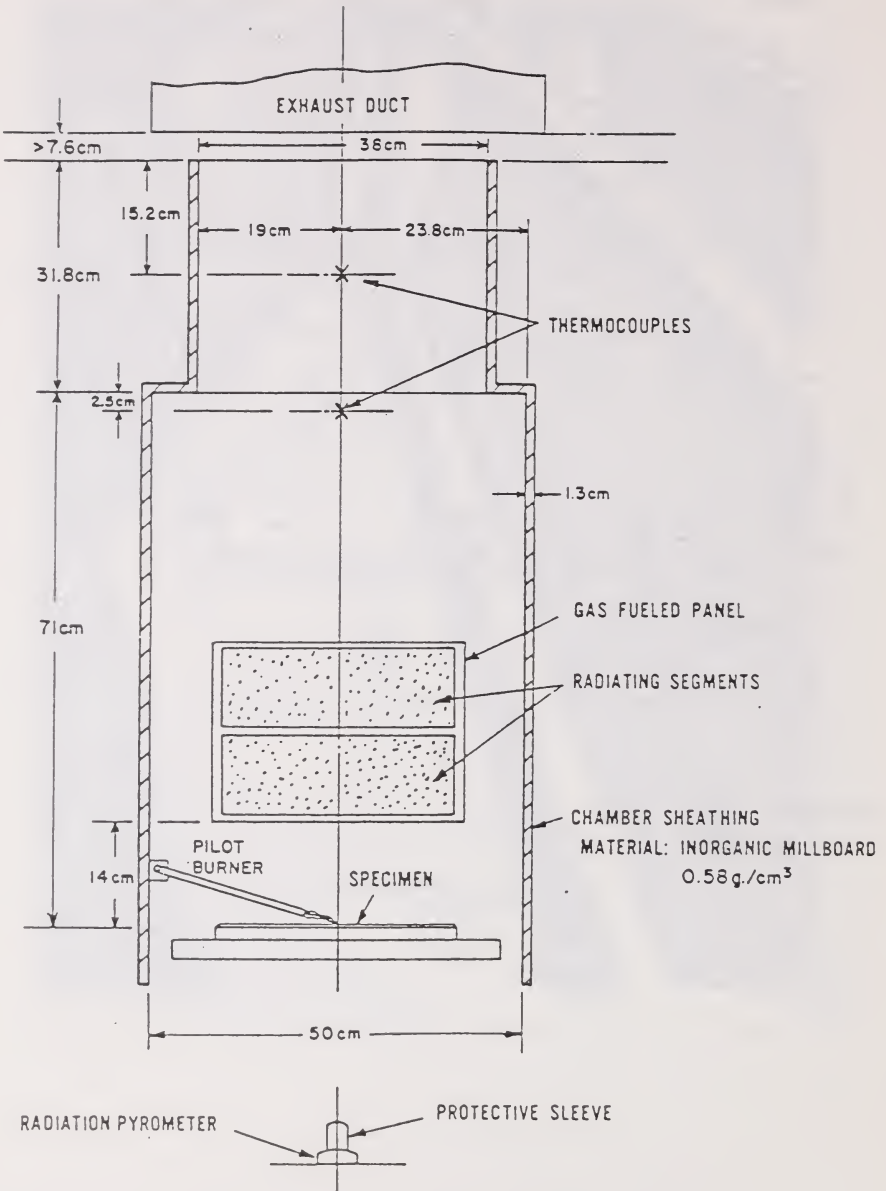
Figure 2





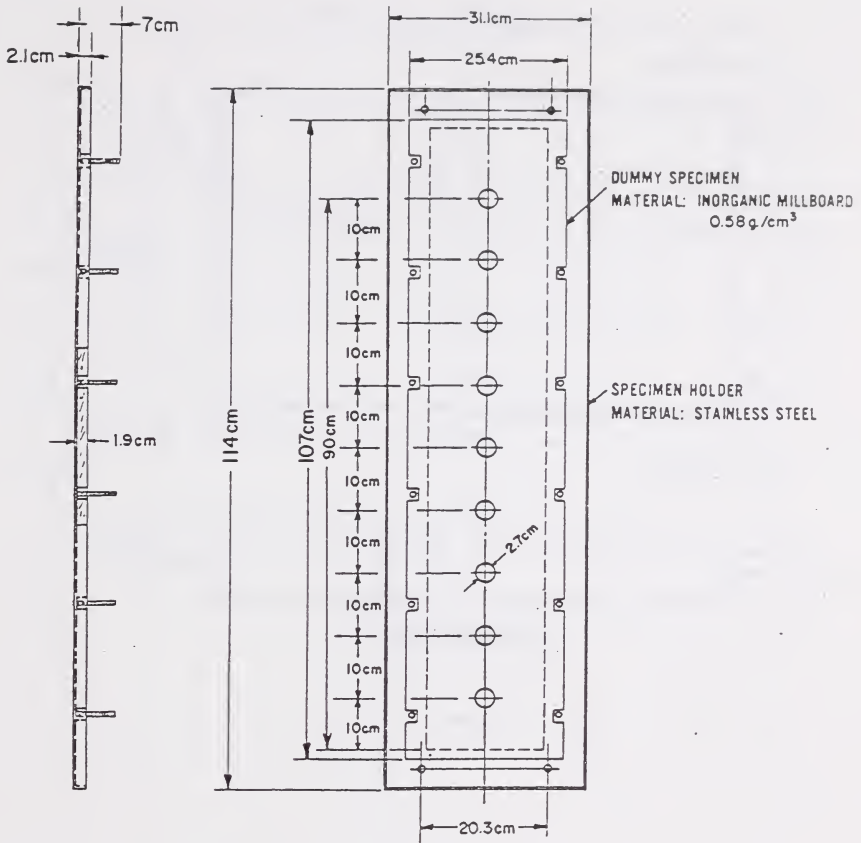
FLOORING RADIANT PANEL TESTER SCHEMATIC  
SIDE ELEVATION

Figure 3



FLOORING RADIANT PANEL TESTER SCHEMATIC  
LOW FLUX END, ELEVATION

Figure 4



DUMMY SPECIMEN IN SPECIMEN HOLDER

Figure 5

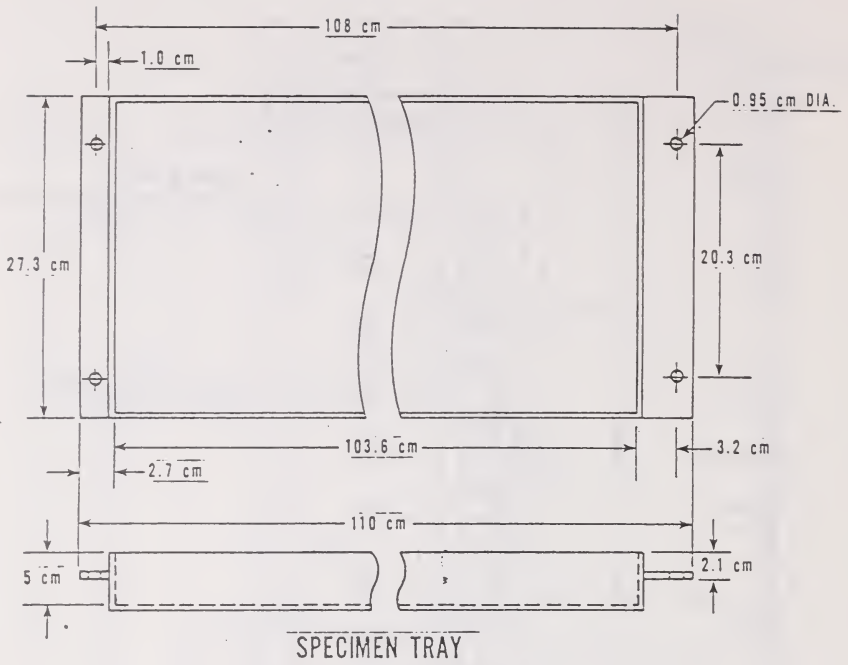


Figure 6



## RADIANT FLUX PROFILE

Date \_\_\_\_\_

Black Body Temperature \_\_\_\_\_ m.v. . \_\_\_\_\_ °C (°F)

Gas Flow \_\_\_\_\_ NTPm<sup>3</sup>H (SCFH) Air Flow \_\_\_\_\_ NTPm<sup>3</sup>H (SCFH)

Room Temperature \_\_\_\_\_ °C (°F)

Air Pressure \_\_\_\_\_ Gas \_\_\_\_\_ cm (in) of H<sub>2</sub>O

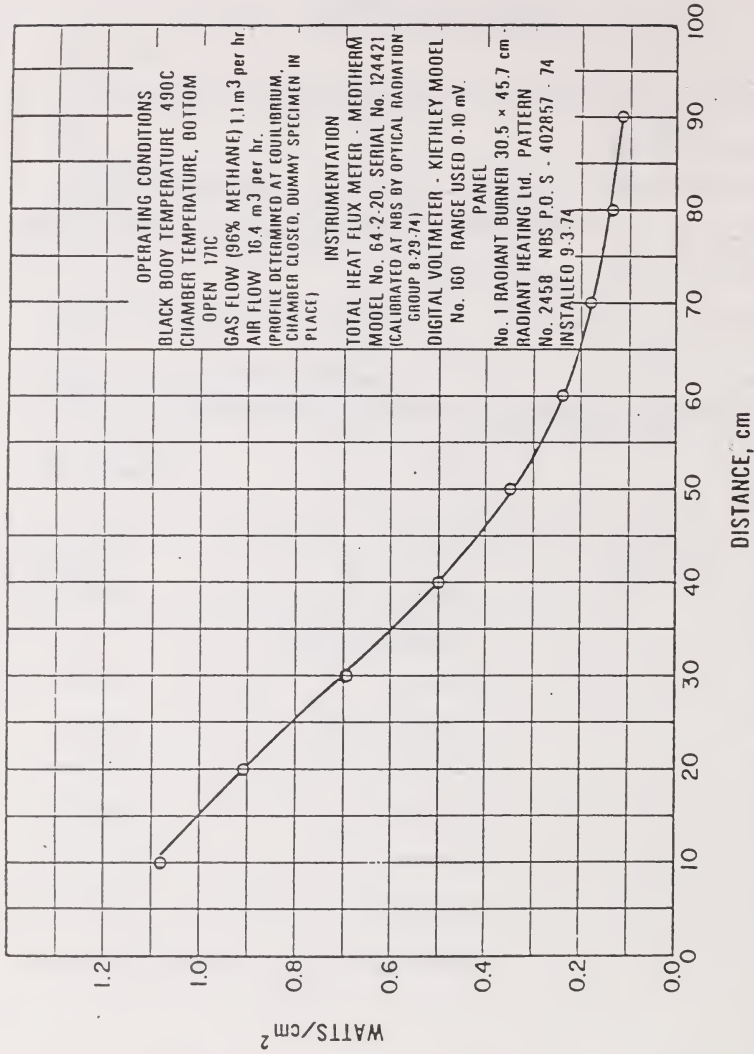
Flux Meter \_\_\_\_\_ Conversion Factor \_\_\_\_\_

Radiometer No. \_\_\_\_\_ from Calibration on \_\_\_\_\_

Distance (cm)	MV	Watts/cm <sup>2</sup>
10	_____	_____
20	_____	_____
30	_____	_____
40	_____	_____
50	_____	_____
60	_____	_____
70	_____	_____
80	_____	_____
90	_____	_____

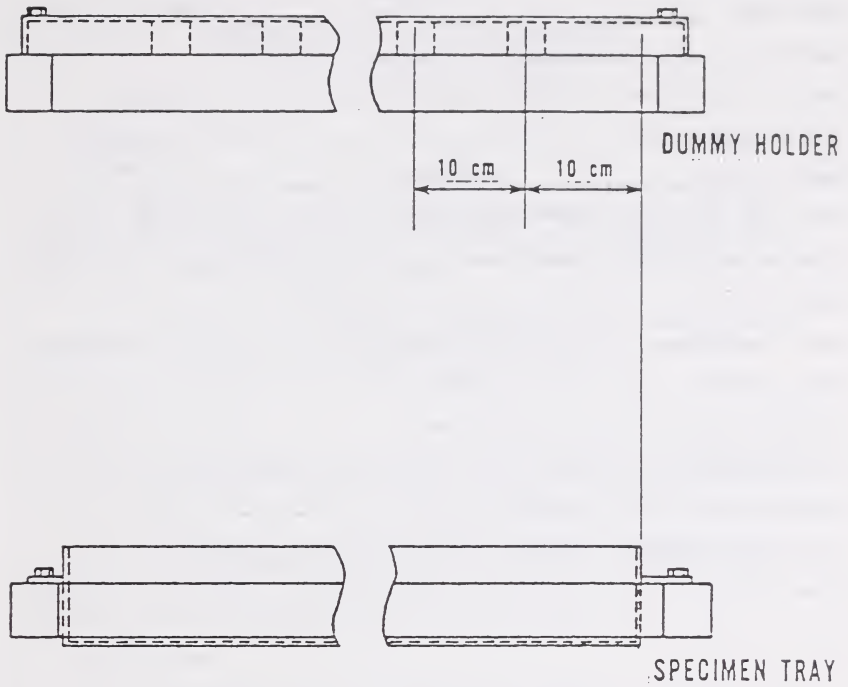
Signed \_\_\_\_\_

Figure 7. Flux Profile Data Log Format



STANDARD RADIANT HEAT ENERGY FLUX PROFILE

Figure 8



## SPECIMEN TRAY MOUNTING POSITION

Figure 9

Test Number \_\_\_\_\_ Date \_\_\_\_\_ Time \_\_\_\_\_  
 Laboratory \_\_\_\_\_  
 Specimen Identification/Code No. \_\_\_\_\_  
 Test Assembly: \_\_\_\_\_  
 Panel: Angle \_\_\_\_\_ ° Temperature \_\_\_\_\_ °C (°F)  
 Flow: Gas \_\_\_\_\_ NTPm<sup>3</sup>H (SCFH) Air \_\_\_\_\_ NTPm<sup>3</sup>H  
 Pressure, cm (in) E<sub>2</sub>O: Initial, Air \_\_\_\_\_ Gas \_\_\_\_\_  
 Chamber Temperature (Initial) \_\_\_\_\_ °C (°F)  
 Room: Temperature \_\_\_\_\_ °C (°F) Hood Draft \_\_\_\_\_ cm (in) water  
 Flame Front Out \_\_\_\_\_ min.  
 All Flame Out \_\_\_\_\_ min.  
 Total Burn Length \_\_\_\_\_ cm (in)  
 Critical Radiant Flux watts/cm<sup>2</sup> \_\_\_\_\_  
 Flux Profile Reference \_\_\_\_\_  
 Observations:

Signed \_\_\_\_\_

Figure 10. Insulation Radiant Panel Test Data Log Format



## APPENDIX C

STANDARD METHOD OF TEST FOR SMOLDERING  
COMBUSTION CHARACTERISTICS OF MATERIALS  
USED FOR THERMAL INSULATION

## 1. Scope

1.1 This method evaluates the tendency of thermal insulation in the form of loose fill, batts or blankets to support smoldering combustion. It is applicable to any insulation that is capable of being installed in the specimen holder at the density and in the physical state of the material in its intended use.

1.2 The purpose of this test is to determine the tendency of the material under test to support and propagate smoldering combustion subsequent to exposure to a standard ignition source.

## 2. Summary of Method

2.1 This method measures the extent and progression of smoldering from a lighted cigarette inserted vertically, with the lit end upward, into the center of an insulation material sample.

2.2 The extent of damage to the test specimen, as indicated by percent of specimen weight loss and by the extent of charring, are recorded in this test, as well as any other observable combustion behavior, such as progression to flaming combustion.

## 3. Significance

3.1 This method of test is designed to provide a basis for evaluating the tendency of insulation to support smoldering combustion when subjected to a small ignition source. The lighted cigarette represents a typical ignition source which may make contact with insulation installed in residential buildings.

## 4. Apparatus

## 4.1 Specimen Holder

4.1.1 The specimen holder shall be an open-top  $20 \pm 0.2$  cm square box,  $10 \pm 0.2$  cm in height, fabricated from a single piece of  $0.61 \pm 0.08$  mm thick (24 U.S. Standard gauge) stainless steel sheet with the vertical edges of the box overlapped, not to exceed to 7 mm in seam width, and soldered so as to be watertight.

4.1.2 The specimen holder during test use shall rest upon a pad of inert insulation, such as of glass or ceramic fibers, of at least 1.5 cm in thickness and approximating the dimensions of the bottom

of the specimen holder. The density of the insulation shall be  $50 \pm 15$  Kg/m<sup>3</sup>.

#### 4.2 Ignition Source

4.2.1 The ignition source shall be a cigarette without filter tip made from natural tobacco,  $85 \pm 2$  mm long with a tobacco packing density of  $0.270 \pm 0.020$  g/cm<sup>3</sup> and a total weight of  $1.1 \pm 0.1$  gm.

#### 4.3 Balance

4.3.1 A balance of 1 kg capacity, accurate at least to 0.1 g, and provided with a suitable scale pan is required.

#### 4.4 Test Area

4.4.1 The test area shall be draft-protected and equipped with a suitable system for exhausting smoke and/or noxious gases produced by testing. Air velocities as measured by a hot wire anemometer in the vicinity of the surface of the sample shall not exceed 0.5 m/sec.

4.4.2 The test area shall be maintained at  $23 \pm 5$  °C and  $50 \pm 5$  percent relative humidity.

#### 4.3 Sampling

4.3.1 At least three samples shall be prepared of any material undergoing test. Samples shall be taken in a manner to encompass possible variations in material composition (for example, from the top, middle, and bottom of bagged insulation).

4.3.2 Samples of material to be tested shall be selected, prepared, and handled in a manner to avoid differences in the composition and condition of the sample from that of the sampled material in its intended use.

### 5. Test Procedure

5.1 Samples and cigarettes shall be conditioned in air at a temperature of  $23 \pm 5$  °C and a relative humidity of  $50 \pm$  percent for at least 12 hours prior to test. Samples and cigarettes shall be removed from any packaging and exposed in a suitable manner to permit free movement of air around them during conditioning.

5.2 Sample material shall be loaded into specimen holders to uniformly and homogeneously fill the holders level and flush to the top edges of the holders. Specimen weight shall be measured, at least to the nearest 0.2 g, by weighing the holder before and after filling. The density of the specimen contained in a holder (volume 4 l, 0.14 ft<sup>3</sup>) shall be calculated and shall be not less than the density recommended for the material in its intended use.

5.3 With the sample in the holder and placed on the insulated pad, a rod of 8 mm diameter with a pointed end shall be inserted vertically into the center of the material being tested and withdrawn to form an appropriate cavity for the ignition source. A well lit cigarette, burned not more than 8 mm (0.3 in), shall be inserted in the formed cavity, with the lit end upward and flush with the sample surface.

5.4 Burning of the cigarette and specimen shall be allowed to proceed undisturbed in the test area for at least 2 hours or until the smoldering is no longer progressing.

5.5 After completion of burning and after the holder has cooled down to 25 °C, the specimen holder with its material residue shall be weighed, at least to the nearest 0.2 g, and the percent weight loss of the original specimen calculated.\*

5.6 After completion of burning, the minimum distance of charring or smoldering of the material from the edge of the holder shall be measured. In cases where the material tested has smoldered to some extent, the material residue shall be carefully removed by layers and the closest proximity of charred material to the vertical sides of the specimen holder determined to the nearest 0.5 cm.

## 6. Criteria

6.1 Materials tested by this method shall be judged in terms of the following criteria:

6.1.1 Weight loss of each specimen expressed as a percent of its initial weight.

6.1.2 Charring of specimen in terms of progression to within 4 cm of the sides of the specimen holder.

6.1.3 Evidence of flaming combustion of the specimen during testing.

## 7. Report

7.1 The report shall include the following:

7.1.1 Identification and/or description of the material being tested.

7.1.2 The original weight of specimens tested and their calculated density.

7.1.3 The final weight of specimens tested and the percent weight loss they have experienced during testing.

7.1.4 The closest distance that charring in specimens tested has approached the sides of the specimen holder during testing, when appreciable charring of a specimen has occurred.

7.1.5 Any observations of the burning characteristics of the specimens that could be pertinent to the material's performance in its intended use.

\*The weight of the cigarette residue is ignored in this exercise and may, in some cases, result in a slight gain in sample weight.

## APPENDIX 2


**UNDERWRITERS LABORATORIES INC.**

CHICAGO NORTHBROOK, ILL. MELVILLE, NY SANTA CLARA, CALIF.

*an independent, not-for-profit organization testing for public safety*

Subject 44

 Melville, New York  
 March 30, 1977

To: Electrical and Fire Councils of Underwriters Laboratories Inc., Attendees of the March 7, 1977 Meeting Sponsored by UL, and Others Interested

Subject: Report on Meeting Concerning the Effect of Thermal Insulation on Electrical Building Wire and Cables

On March 7, 1977 a meeting was held at La Guardia Airport, New York, for the purpose of discussing the effects of thermal insulation on the operating characteristics of electrical building wire and cables, and on electrical devices such as outlet boxes, "self-contained" receptacles, etc.

The following individuals attended the meeting:

Messrs: L. A. Barron	National Cellulose Insulation Manufacturers Association
J. Bohr	Oren Corporation
J. Bono (Chairman)	Underwriters Laboratories Inc.
M. Daley	CCS/Hatfield Wire & Cable
B. Derbyshire	Thermtron Products Inc.
W. E. Fitch	Owens Corning Fiberglas
R. W. Higgenbottom	Triangle PWC Inc.
E. M. Kane	Cadillac Cable Corporation
H. T. Knox	Collyer Insulated Wire
R. Kolakowski	The Upjohn Company
E. Koloseus	Uniroyal Chemical
E. W. Krawiec	Underwriters Laboratories Inc.
J. V. Lipe	ITT Royal Electric Division
J. Page	NEMA Wire & Cable Division
J. N. Reynolds	Alcan Cable
W. H. Roemer	Cerro Wire & Cable
J. Ruby	Ettco Wire & Cable Corporation
R. W. Seelbach	Underwriters Laboratories Inc.
R. S. Strength	Monsanto Company
D. H. Toy	Rapperswill Corporation
H. H. Watson	Private Consulting Engineer

In self-introductions, the attendees identified themselves as representatives of manufacturers of building wire and cable with one association staff member, producers of thermal insulation with one association staff member, and Underwriters Laboratories Inc.



The following is not intended to be a verbatim transcript of the meeting but covers the essential details of the discussion.

INTRODUCTORY COMMENTS BY CHAIRMAN -- PURPOSE OF MEETING

Mr. Bono opened the meeting by noting that the entire country had been hard pressed by one of the worst winters in our nation's history. The unusual severity of the winter weather coupled with the shortage and rapidly increasing costs of heating fuels have caused renewed interest in upgrading thermal insulation in existing buildings and providing more insulation in new buildings.

It was also noted that legislation originating at both the State and Federal levels, as well as "rule making" activities on the part of public utilities and the regulatory agencies which oversee their operations, would likely make increased thermal efficiency in buildings a mandatory as well as an economic objective.

This wide spread utilization of more efficient thermal insulation may have adverse consequences on the performance of electrical wire and cables, and other electrical devices. Since such devices generate heat, and since wire and cables rely on the integrity of electrical insulation for their safe and efficient operation, it seems obvious that any proposed change in operating conditions which might cause overheating of conductor electrical insulation, with possible resulting damage, requires a careful review. Such a review process apparently has not yet been initiated.

However, those authorities having responsibility for the inspection of electrical systems have begun to recognize the potential for increased electrical system failure due to the use of more efficient thermal insulation. Letters sent to the National Electrical Code - Code Correlating Committee by inspection agencies from various parts of the country have questioned the acceptability of encasing, or otherwise surrounding completely or partially, electrical system components with thermal insulation. The response from the Correlating Committee has been consistent .... Article 310-9 of the NEC prohibits the installation of electrical system components in such a manner as to promote overheating and eventual failure of such equipment.

This would imply that, in the absence of appropriate modifications to the design of the electrical system, such as "derating", the installation of electrical equipment in high efficiency thermal insulation in "new" construction, or, the installation of such insulation in building cavities containing electrical equipment in existing buildings might well be construed as a violation of the National Electrical Code.

The concerns are for potential electrical system damage due to:

1. Overheating during operation of electrical equipment.
2. Overheating due to exothermic heat liberation during curing of some types of insulating materials.
3. Chemical interaction of electrical and thermal insulating materials.
4. Chemically induced corrosion of normal current carrying and grounding conductors, terminals, and fittings.
5. Increased difficulties of "rewiring" after some types of thermal insulating materials are installed.

Also, the inevitable questions of liberation of toxic gases during combustion, effects on "fire rated" assemblies, etc. have been raised.

Given the complexity of the problem, and the apparent lack of prior in-depth analysis, UL in conjunction with NEMA and some producers of thermal insulation decided to convene a meeting for the purpose of facilitating an exchange of technical information, examining any existing data, and discussing the need for additional information, possibly involving future research efforts.

#### PRESENTATION OF DATA

UL provided, by means of a slide presentation, data obtained during two investigations conducted by UL's Electrical Departments. Both test programs involved the study of actual operating temperatures obtained on various cable or wire including nonmetallic sheath cable, armored cable, and wiring in conduit during both "normal" and "abnormal" current flow conditions. Both test programs made use of wood frame type vertical wall sections both with and without insulated cavities. One test program utilized two different thermal insulation systems.

The attendees were cautioned that the data were developed from tests involving selected wiring configurations, specific thermal insulations, and specific simulated building structures. No attempts had been made to duplicate normal internal/external temperature differentials, or to identify and control all other variables inherent in a "real world" building. Nevertheless, comparisons between wiring systems in insulated vs. uninsulated building constructions, within the conditions encompassed by the test parameters, were provided.

As could be anticipated in view of the property of thermal insulation to reduce heat flow, the UL data showed that electrical equipment located in insulated wall cavities operated at higher temperatures than the same equipment in uninsulated wall cavities. With certain wiring systems and certain thermal insulations, and with maximum permissible current flow, the temperature rise on the wiring exceeded the values assigned by the National Electrical Code to the conductors for the specific type of insulation employed.

A summary of additional data required to permit more definitive conclusions was presented. It included the following:

- a) Test data on different wiring configurations and associated components (in conduit, 2 wire AC, flexible metal conduit, ordinary boxes, receptacles, switches, "self contained" receptacles, etc.)
- b) Test data on penetration of electrical components by the thermal insulation with possible attendant arcing, tracking, bridging between terminals, etc.
- c) Study of possible corrosion effects on grounding, terminations and contacts.
- d) Test data on different thermal insulating materials (types, density, coefficient of heat transfer, etc.)
- e) Test data on different installation conditions (attics, wall cavity, vertical and horizontal runs).
- f) Test data on effects of various ampacities.
- g) Study of effects of exothermic reaction of cellular foam.

#### GENERAL DISCUSSION

Representatives of the thermal insulating materials industry were asked to explain the attributes, composition, and methods of installing various materials now in use. Such materials included glass fiber batts and blankets, loose fill mineral insulation (vermiculite and perlite), cellulosic loose fill and cellular plastic in slab or blown form. Members of the electrical equipment industry detailed properties of materials used in their equipment, the assumed operating conditions for which the equipment is designed, and the procedures used to establish equipment ratings under various conditions. This exchange permitted a discussion of the possible areas of concern when electrical system components are in contact with or encased in thermal insulating materials.

It was agreed from the standpoint of logic and from the limited data presented, that encasement in high efficiency thermal insulation would cause higher operating temperatures in the wire and cables. It was not as clear whether actual installations would result in excessively high temperature or what the hazard could be. One participant cited his experience in attempting to cause ignition within a wall cavity filled with his company's insulating material. He concluded that the probability of obtaining ignition was incredibly small, but, that if ignition did occur, the fully insulated wall had the attribute of having eliminated the floor-to-ceiling "chimney" effect common in uninsulated or partially insulated walls. The combustibility of the insulation may well be a factor in determining the fire hazard resulting from high temperature development in the electrical wire and cable.

It was pointed out that heat developed in an electrical cable within an insulated wall would be conducted to the terminals of electrical devices. The increased terminal temperatures could cause premature failure, and possible ignition outside of the insulated wall. Also, a cable manufacturer pointed out that high cable temperatures could cause premature cable failure, and that a fully insulated wall might make "re-wiring" extremely difficult.

It was suggested that there were several ways of reducing the amount of heat generated by an electrical distribution system, or, to minimize the effect of higher operating temperatures. Electrical equipment could be "derated" when installed in a thermally insulated cavity, which would have the effect of requiring larger size conductors, or, equipment with high temperature rated electrical insulation could be used. If necessary, both approaches could be used simultaneously in order to arrive at the most cost effective solution. These measures can readily be accomplished in new construction where it is simply a matter of employing the desired wiring.

The more difficult problem occurs when insulation is applied in existing buildings. A realistic approach might involve "packaging" re-insulation and rewiring as a single building improvement job. The rewiring might be accomplished with exterior perimeter raceway or even interior surface raceway. Including complete or even partial rewiring with the re-insulation job leads to the concern that the "package" job would become economically prohibitive for homeowners.

Members of both industries raised the question of electrical load diversity ... especially as found in residential occupancies, wherein circuits operate at less than their maximum permissible ampacity. Since the tendency to produce overheating of electrical equipment is most pronounced when a distribution system is operated at or near maximum capacity for extended periods of time, or when circuits are overloaded, load diversity associated with residential buildings might well mitigate the instances of dangerous temperature development.

It was stated that there was no known large scale study ever conducted on branch circuit load diversity. Such information exists for service equipment or for equipment in specialized manufacturing or commercial installations. Where demonstrable conditions of load diversity exist, the NEC permits load factors to be included in electrical system design. It is safe to assume that most existing electrical installations have already taken advantage of such load factors.

An insulation manufacturer pointed out that this winter's weather had caused some electrically heated homes to operate with their heaters energized continuously for days at a time. Any load diversity assumed for such an installation was negated by the unusual weather conditions.

UL has found that there is a tendency to design appliances to take advantage of maximum permissible branch circuit capacities. Circuits supplying such equipment may be loaded at, or close to capacity when such equipment is in operation. Finally, it should be recognized that the older home which could benefit most from re-insulation may likely be in need of upgrading of its electrical system. There is nothing to prevent a homeowner from overloading his originally adequate wiring system with new appliances.

A question was raised as to how many incidents of fire development could be documented as having resulted from the use of thermal insulation in contact with or surrounding electrical cables. Although no authoritative information was available, there are fires attributed to electrical causes but the specific electrical feature responsible for the fire was seldom pin-pointed.

It was observed that wiring insulation, as currently employed, was capable of withstanding occasional periods of overheating without breakdown, particularly if the wiring was fixed and not subjected to flexing or other movement.

In response to a question, an electrical equipment manufacturer stated that it would not be practical to call a 15 amp branch circuit anything else simply because the cable ran through a insulated wall. He suggested that one possibility might be use of a non-tamperable 10 amp or less trip-current overcurrent protective device in order to legitimately down-rate existing branch circuits when a house is re-insulated. It was concluded that this could lead to frequent nuisance tripping of the overcurrent device.

Down rating some existing circuits in this way would not eliminate the problem of "dedicated" circuits, such as those supplying heating or air conditioning equipment. Also, the distribution panelboard would have to be replaced with one which could accept the new overcurrent devices.



Subject 44

-7-

March 30, 1977

The discussion was summarized by stating that there was sufficient evidence to indicate the need for additional study of the potential problem when high efficiency thermal insulation is used in contact with electrical equipment, particularly wire and cable. This study should attempt to determine whether the problem was serious and should, of course, recognize the balancing social need to conserve energy.

It appears that the National Electrical Code should address the issue more clearly, particularly to provide guidance when insulation of buildings is contemplated. Additional data are needed.

It was urged that the attendees advise their associations and companies about the issues discussed at this meeting with the suggestion that files be searched for pertinent information which might be of value, and to consider development of data required to provide a better assessment of the problem. In this respect, it was noted that a research proposal by the Energy Research and Development Administration, relating to the study of proposed reinsulation systems, includes reference to the need to consider the effect on electrical systems.

The meeting was adjourned with thanks to all participants for their interest and contributions.

\*\* \*\* \*

Any comments concerning the report of the discussion should be addressed to Jack Bono, Assistant Chief Engineer - Fire Protection, at UL's Melville office (1285 Walt Whitman Road, Melville, Long Island, New York 11746).

UNDERWRITERS LABORATORIES INC.

E. W. KRAWIEC  
Senior Project Engineer  
Electrical Department

REVIEWED BY:

JACK BONO  
Assistant Chief Engineer  
Fire Protection  
Melville Electrical Department

## APPENDIX 3

NINETY-FIFTH CONGRESS

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J. THOMAS GREENE  
 COUNSEL TO THE CHAIRMAN

BENARD J. WUNDER  
 MINORITY COUNSEL

MEMORANDUM;

DATE: February 21, 1978

TO: Honorable John E. Moss, Chairman

FROM: John R. Galloway, Energy Task  
Force Director

SUBJECT: Additional Reports of Corrosion Attributed  
to Cellulose Insulation

The Subcommittee staff recently learned of two cases in California where serious corrosion damage to homes has been attributed to cellulose insulation.

Both instances involve a wet cellulose insulation material manufactured by Reliable Insulation Co., Napa, California.

Case #1: According to information developed by a Federal Trade Commission investigator, Reliable Insulation Co. insulating material caused the corroding of the pipes and wiring in 30 condominium units under construction in Tiburon, California in 1974. The resulting leakage from the copper water piping pulled apart the ceilings and walls, according to the local building inspector. A testing laboratory found the insulation to pose "a continuing corrosion problem in connection with copper pipe and gas pipe installation." The latter condition, according to the laboratory report, carried with it "the probability of a gas line leak with the possibility of an explosion occurring."

The damaged pipes and electrical wire in the 30 living units were replaced prior to a \$100,000 out-of-court settlement. (For further details see Attachments I-III.)

Case #2: Reliable Insulation is currently involved in a lawsuit wherein its cellulose insulation was alleged to have caused corrosion damage to 13 townhouses in Pleasanton, California. There the corrosion is alleged to have caused damage to the metal pipes, wiring, and electrical outlet boxes.

Information developed by the Subcommittee staff and the FTC suggests that Reliable Insulation purchased the chemicals used in the manufacture of the insulation from Napa Fertilizer Company.

A lawsuit is pending. (For further information see Attachment IV.)

JRG:j

ATTACHMENT I

Federal Trade Commission

CR

## INTERVIEW REPORT

CR-6

NAME AND OFFICIAL POSITION Mr. Walter Louis President	FILE NO.(S) P711008
FIRM NAME AND ADDRESS Walter Louis Plumbing & Heating, Inc. 52 Woodland Avenue San Rafael, California	
PLACE OF INTERVIEW	DATE 8/11/77

Informant was the heating and plumbing contractor on a project called Marinero Heights at 53 Marinero Circle, Tiburon, California. Before the project was completed, problems arose involving the corrosion of the copper piping installed. Informant's recollection of the incident is as follows:

The project, Marinero Heights, was owned and being built by Deak Investment Corporation of San Francisco. The primary construction contractor was Smith & Haley, 43 Panorama Way, Walnut Creek, California, and informant was the subcontractor for the plumbing and heating. The project consisted of ten buildings containing 36 units. About the time that the insulation was being installed, a problem developed with the piping. A check revealed that the pipes were corroding in 30 of the 36 units under construction. The 6 units where the problem did not occur were those where there was no insulation applied. The insulation, a wet cellulose type was being blown into the walls by Allied Insulating Service Co. of Hayward, California. The material used had been supplied to Allied by Reliable Insulation Company, Napa, California. In order to protect himself, Mr. Louis filed an insurance report with Lund Associates of San Rafael, this at the request of Mr. John J. Schuck, Vice-President of Lund Associates. See Mr. Schuck's calling card attached and identified as Louis Exhibit 1(a). Attached and identified as Louis Exhibits 1(b-c) are copies of the claim filed by Mr. Louis.

In order to determine the cause and the responsibility for the corroding of the pipes and wiring, Mr. Louis had tests made by Metallurgical Laboratories, 1142 Howard Street, San Francisco, California. Copies of the test results are attached and identified as Louis Exhibits 2(a-d). The tests indicate that "The Water Soluble Acid Sulfates From the Fibrous Organic Insulation Product Would Corrode Copper Pipe Rapidly". This conclusion is also set out in a letter dated May 15, 1974, from Mr. Martin Quist of Metallurgical Laboratories. A copy of the letter is attached and identified as Louis Exhibit 3.

## Federal Trade Commission

## INTERVIEW REPORT (Continued)

PAGE NO. 2

NAME	FILE NO. (S)
Mr. Walter Louis	P711008

On May 31, 1974, a letter was received from Dave Haley, Smith & Haley Construction Inc. requesting the assistance of Mr. Louis' insurance company in getting the matter adjusted by the insurance companies for Allied and Reliable. A copy of the letter is attached and identified as Louis Exhibit 4.

Attached and identified as Louis Exhibit 5 is a copy of a letter from Mr. Louis requesting Metallurgical Laboratories to supply copies of the test reports with attorney's for Deak Investment Corporation.

Informant does not recall how much of the insulation was reinstalled but stated that in his opinion no further damage would come from the insulation once it dried.

Attached and identified as Louis Exhibits 6 and 7 are calling cards of representatives of Allied and Reliable who called on Mr. Louis at the time this problem occurred. While Reliable Insulation Co. is still in operation, no trace could be found of Allied Insulating Service Co.

*KGP*  
Kerper G. Propert  
Consumer Protection Specialist

San Francisco  
August 17, 1977  
KGP:mlb

ATTACHED 8-11

Federal Trade Commission

CR

CR-4

## INTERVIEW REPORT

NAME AND OFFICIAL POSITION Mr. Phil Scott Building Inspector	FILE NO. (S) P711008
FIRM NAME AND ADDRESS City of Sebastopol Sebastopol, California	
PLACE OF INTERVIEW By telephone (707) 823-8597	DATE 8/9/77

Informant was contacted for the purpose of securing information relating to a building inspection he made while employed as a building inspector in Tiburon, California, in 1974. He stated substantially as follows:

Back in 1973 or 1974, informant was making an inspection of a condominium building site known as Marinero Heights in Tiburon, California. At the time, he noticed that the ceilings and walls of some of the units were pulling apart. A further inspection revealed that the copper water pipes were corroding. While no official report was made of these problems, it was corrected and the damaged pipes and wiring replaced, as well as some of the insulation.

*G. Probert*  
Kerper G. Probert  
Consumer Protection Specialist

San Francisco  
August 17, 1977  
KGP:mlb



ATTACHMENT

1142 HOWARD STREET • SAN FRANCISCO, CALIFORNIA 94103 • AREA CODE 415 863-0575

May 15, 1974

Julien Louis, Plumbing Division, Inc.  
 52 Portland Avenue  
 San Rafael, California 94901

Gentlemen:

Laboratory Reports  
 Nos. 5152, 5341 and 5342

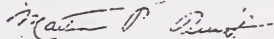
The laboratory reports covering the various samples of insulation products clearly indicate that these insulation products would be a continuing corrosion problem in connection with copper pipe and gas pipe installations. The acid sulfates contained in the insulation when combined with moisture would have a continuous corrosive effect on the pipes. The moisture, no doubt, would be present in varying degrees due to heating and cooling of the pipes resulting in condensation of moisture on the pipes and insulation therefore creating the acid water soluble sulfates and the corrosive action on the pipes.

In particular, we would like to draw your attention to the probability of a gas line leak with the possibility of an explosion occurring.

If you have any further questions, please do not hesitate to call.

Sincerely yours,

METALLURGICAL LABORATORIES, INC.



Martin P. Quist

MPJ:s

Send Original and Copy to  
 Dave Haley - 5-17-74

ATTACHMENT IV

Furnished by FTC

Barry Stubbs  
Attorney

P711008

80 Stonestown  
San Francisco, California

At the above address

Aug. 25, 1977

Informant is an attorney for the Stoneson Corporation, 3150 20th Avenue, San Francisco, California. He stated substantially as follows:

In 1973 the Stoneson Corporation was building a number of homes in a development known as Stoneridge in Pleasanton, California. The primary contractor for the homes was Smith & Haley of Hayward, California. They in turn sublet the insulation of the homes to Ross Insulation Company (out of business) who insulated the homes with an insulation material purchased from Reliable Insulation Company of Napa, California. The homes were insulated in December of 1973 using "Rimco Cellu-Seal" and in April of 1974 water damage was noted in a number of the homes. Since it did not rain for some time, Stoneson became suspicious and upon inspection of the homes, noted that many of the metal pipes, wiring and electrical outlet boxes had corroded.

Samples of the insulation material used in several Stoneson tracts were tested by Truesdail Laboratories, Inc., 4101 North Figueroa Street, Los Angeles, California, and it was found that most of the insulation caused corrosion. A summary of the test reports was sent to Mr. Stubbs in a letter dated April 21, 1975, a copy of which is attached and identified as Stubbs Exhibit 1(a-b).

It appears that Ross was originally using "Rimco Cellu-Seal" that contained a sufficient amount of borax to prevent corrosion but when borax became hard to secure, Reliable switched to "ammonium sulfate and ammonium bisulfate" which caused "severe corrosion." A lawsuit was filed against Ross and Reliable and is still pending.

Mr. Stubbs stated that the same problem occurred in Alameda County at a development called Garden Isle Project. This project was being built by Braddock and Logan with the superintendent being a Mr. Gram. The suppliers of the insulation was Reliable and the installer was also Ross.

Kerper G. Probert  
Consumer Protection Specialist

San Francisco  
September 7, 1977  
KGP:mlb

## APPENDIX 4

NINETY-FIFTH CONGRESS

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 HOUSE OF REPRESENTATIVES  
 SUBCOMMITTEE ON OVERSIGHT AND INVESTIGATIONS  
 OF THE  
 COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE  
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 COUNSEL TO THE CHAIRMAN

BERNARD J. WUNDER  
 MINORITY COUNSEL

MEMORANDUM

DATE: February 17, 1978

TO: John E. Moss, Chairman

FROM: Energy Subcommittee Staff

SUBJECT: Cellulose Insulation and Corrosion  
 Problems in Wisconsin

In November, 1977, you instructed the staff to review reports of a roof collapse in Wisconsin that had been attributed to corrosion associated with cellulose insulation.

Subsequent staff inquiry determined the following:

1. On August 9, 1975, a cheese warehouse, owned by the Outagamie Producers Cooperative collapsed. The structure was a metal building that was five years old at the time of failure. Loose fill cellulose insulation had been blown into the attic space between the roof and the finished ceiling at the time of construction. The insulation was manufactured by Pal-O-Pak Insulation Co. of Hartland, Wisconsin.

An investigation by Wisconsin state authorities (enclosure B) determined that the insulation in question contained aluminum sulfate used as a fire retardant and that moisture in the attic space had combined with the aluminum sulfate to form sulfuric acid which in turn destroyed the metal struts that supported the roof.

2. Shortly after the Outagamie County building collapse, an identical problem was found in a second metal building that had been insulated with Pal-O-Pak cellulose insulation, although failure had not yet occurred.

3. Following these two incidents, the state obtained a list of all similar buildings insulated with Pal-O-Pak products. Subsequent inspections indicated that "wherever moisture had been introduced into the insulation, oxidation of the metal panel occurred." Of these 41 buildings, 20 were found to have undergone corrosion. Half of these cases were serious.
4. Pal-O-Pak insulation has been involved with other corrosion problems. The attached photographs were taken in Apartment 1 of a five-family unit built in 1973 in Rochelle, Illinois. The photographs show the damage done to the bathroom copper piping due to corrosion by Pal-O-Pak insulation.

m  
Enclosures



State of Wisconsin \ DEPARTMENT OF INDUSTRY, LABOR AND HUMAN RELATIONS

201 E. WASHINGTON AVENUE, MADISON, WISCONSIN

671 DEC 28 PM 4:21

RECEIVED

December 21, 1977

SUBCOMMITTEE ON  
OVERSIGHT & INVESTIGATIONS

PLEASE REPLY TO:

SAFETY & BUILDINGS DIVISION  
P. O. BOX 2846, MADISON, WISCONSIN 53707

The Honorable John E. Moss, Chairman  
Subcommittee on Oversight & Investigations  
of the Committee on Interstate & Foreign Commerce  
Rayburn House Office Building, Room 2323  
Washington, D.C. 20515

Dear Congressman Moss:

This letter is in reply to your November 22, 1977 request for inspection reports on buildings containing cellulose insulation.

Enclosed are copies of the inspection reports. In addition, I have included a summary statement indicating the reason why the inspections were ordered. The inspections were prompted as a result of two building failures which appeared to have been caused by moisture collecting in the cellulose, an acid being formed from the reaction of the moisture and salt used for flame retardancy, and the acid destroying the structural metal panel of the building.

If you need any additional data or information on this subject, please advise and I'll forward the information.

Very truly yours,

L. L. Litchfield, P.E.  
Assistant Chief Engineer

LLL:rk:19/4

Enc.



## SUMMARY STATEMENT--CELLULOSE INSULATION BUILDING FAILURE

On August 9, 1975, the Outagamie Producers Cooperative Cooler warehouse building collapsed. An investigation revealed that the structure was a metal building manufactured by the Behlen Manufacturing Company and consisted of their convex double panel configuration. The double panel formed the roof covering and also provided a finish ceiling. The panels also served as the chord members of the truss system. Since a finished ceiling was provided, the resulting attic space was used for the placement of insulation; in this case a cellulose insulation manufactured by the Pal-O-Pak Insulation Company, Inc. was used.

The building was kept at a near constant temperature (35°-40°) and was approximately five years old at time of failure. The building panels were noticed to have extensive oxidation of the metal surface and, since the building failure occurred rather slowly, loss of effective section area by oxidation was suspected. Therefore, a chemical analysis of the insulation was ordered. The State Laboratory of Hygiene report indicated that elements in abundance included sulfur, iron and aluminum. Upon consultation with the cellulose manufacturer, it was found that aluminum sulfate was used as a fire-retardant additive to the insulation. Due to the temperature difference, moisture was produced and held in the attic space. The moisture combined with the aluminum sulfate to form sulfuric acid which, in turn, destroyed the metal panel.

Shortly after the building failure, information was submitted that a similar building in Greenwood was experiencing identical problems, even though failure had not occurred. An investigation indicated that the structure was a Behlen double panel building using the same structural panels (with a flat roof instead of convex) and containing the same insulation. The steel panels had deteriorated approximately 50% of the cross-sectional area. The owner indicated that the roof was to be replaced and a different type of insulation used.

As a result of the two similar incidences, the design engineer, J. F. Pezl, and the contractor were asked to submit a list of all other similar buildings containing the cellulose insulation. An inspection of each facility was made by the field staff to order any corrective action necessary to insure a structurally sound building.

The inspections indicated that wherever moisture was in the insulation, oxidation of the metal panel occurred. Moisture was produced by roof leaks and condensation. Roof leaks were found to be the predominate problem. Roof leaks affected a small area of the total structure; therefore, repair work, where needed, could be facilitated. The two cooler buildings, previously discussed, were found to have the worst oxidation as a result of the condensation formed by temperature difference. To date, all corrective work has been ordered.

## APPENDIX 5

## ITEM A

STATEMENT ON THE DEVELOPMENT, USE AND SIGNIFICANCE OF  
THE UL723 TUNNEL TEST STANDARD

This statement is intended to briefly summarize the development and use of the Steiner Tunnel Test Method for the evaluation of the flammability of cellular plastics and other building construction materials.

Following the development of the tunnel equipment by A. J. Steiner and his associates the first formal test Standard (UL723) was published by the Laboratories in August, 1950 with revised editions in 1958, 1960 and 1971. The test was adopted by the American Society for Testing and Materials as a tentative standard in 1950 and formally adopted in 1961 with revised editions in 1960, 1970 and 1972. The tunnel test was formally adopted as a Standard of the National Fire Protection Association (NFPA No. 255) in 1955 with revised editions in 1958, 1961, 1966, 1969 and 1972. The test method was approved as an American National Standard by The American National Standard Institute (A2.5) in 1963, with a revised edition in 1970.

Prior to development of the tunnel equipment, test methodology available in the fire protection field dealt primarily with (1) the prevention of the occurrence of fire, (2) early detection and warning, (3) confinement with fire resistant structural components (e.g., walls and partitions, columns, floors and ceilings, doors, etc.) and (4) extinguishment.

Although each of these aspects of the fire problem were important and established practices that were basic to the science, no direct consideration was given to the burning characteristics of the surfacing materials used in building construction. The periodic occurrence of major fires, involving the rapid spread of fire, high death tolls and, more often than not, large property losses, aroused public concern. This clearly indicated the need to establish test methodology on the burning characteristics of materials, which ultimately led to the development of the tunnel test method for classifying fire performance characteristics of materials, specifically: the spread of fire, the amount of heat generated and the production of smoke and particulate under controlled fire conditions.

Measurements are presented in the form of classification values for: (1) flame spread, (2) fuel contributed and (3) smoke developed. These values are expressed as ratios of the data developed for the test materials to related data established for untreated red oak lumber as 100 and asbestos-cement board as zero on the classification scale. These classification values constitute measures of the surface burning potential of materials under progressive flaming conditions, brought about by the rates-of-release of combustible volatiles and heat from the materials.

The tunnel test fire exposure conditions (4-1/2 ft long test flame, covering nearly 7 sq ft of the 36 sq ft of exposed specimen surface, and generating ignition energy at 5000 BTU per min over a 10 min period) uniquely permit the severe fire exposure of a broad range of material compositions, composites and assemblies.

Prior to 1960 the tunnel test was used primarily for the evaluation of the surface burning characteristics of homogenous compositions of ceiling and wall finishes, such as, acoustical tiles, wall coverings, coatings and various types of decorative paneling.

Through adaptation (Appendix added to Standard in late 1960's entitled: "Guide To Mounting Methods") the procedure was expanded to include the evaluation of composites and assemblies. The Laboratories now use 30 individual categories to describe product classifications promulgating tunnel test results, including: acoustical, insulating and general purposes tiles, boards and panels, batt and blanket insulations, composite building units, sections and panels, fire retardant and general purpose coatings, loose-fill insulations, treated and untreated plywoods, lumbers and wood composition boards, foamed, molded, reinforced and laminated plastics and sheet type wall coverings.

There are now ten (10) tunnel facilities active in the U.S. and Canada in addition to the two operated by UL. An ASTM Task Group of tunnel operators is now working at comprehensive design, operational and procedural revisions to provide additional guidance to promote uniformity between facilities, pursuant to the conduct of an extensive, multi-faceted interlab study, involving all active facilities. Precision statements will be developed for various classes of materials based upon the results of this study and previous interlab test series coordinated by Underwriters Laboratories Inc. (1958-1968) and the National Bureau of Standards (1973).

The ability of the tunnel test to identify the surface burning characteristics of materials, composites and assemblies, known to have been causative factors in major fires throughout the U.S. (e.g., paneling from various early hotel fires, hospital fires, school fires, nursing home fires, fires in military installations and government facilities, etc.), together with the results of several full-scale fire studies conducted by other organizations, led to reliance on the method by building officials, rating bureaus, fire services, insurance groups, government agencies and other authorities for establishing compliance with Municipal, State and National requirements on all forms of interior finish materials.

The tunnel test method has been adopted by all four of the Model Building Codes and is used by regional and local code authorities for providing fire performance data for the evaluation of the flammability of interior finish materials. Codes and Standards writing organizations, designers, architects, safety engineers, etc. use tunnel test data to specify material performance requirements based upon occupancy type and locations within occupancies. Lower flame spread classified materials are required in occupancies and locations where egress may be difficult or critical (i.e., theaters, hospitals, schools, nursing homes, places of public assembly, etc.). Higher flame spread classified materials may be permitted in open office areas, warehouses, etc.

Flammability evaluations by the Laboratories of cellular plastics for building construction, using the Steiner Tunnel, began with the testing and classification of a flame retardant formulation of polystyrene foam board stock in 1960, with subsequent investigation of polyurethane type boards incorporating flame retardant resin systems (1st Generation) beginning in 1964, polymerically and chemically modified flame retardant polyurethane type formulations (2nd Generation) in 1965, polyisocyanurate type foams initiated in 1968 and, most recently, urea formaldehyde type cavity-fill foams. Spray applied and poured-in-place cellular foam system investigations were originated in 1968 and 1972, respectively.

Over the period, from 1960 through 1973, in excess of 2000 tunnel tests have been conducted on polystyrene, polyurethane, polyisocyanurate and urea formaldehyde cellular plastics, in board stock, spray applied or pour-in-place forms, yielding flame spread values ranging from less than 5 to over 2000.

Voluminous fire experience records describing the performance of high flame spread (classified by the tunnel test) interior materials are available at the National Fire Protection Association records center in Boston, Massachusetts. A review of these fire records (see Appendix of this Statement) covering a three-year period (1962-1965) conducted in the latter part of 1965, revealed that flame spread from the initiating fire source to other areas of a building or compartment will trap occupants and cause extensive property damage. The combustible cellulosic fiber boards, decoratively coated plywood paneling, hardboard, paper boards, etc., identified in these fire reports, and representative of interior finish materials used at that time, developed relatively high flame spread classification values, ranging from 160 to well in excess of 200 by the tunnel test, indicative of the performance of the materials as observed in the fire reports.

Over the past 13 years, several opportunities have developed wherein the Laboratories has been able to conduct various fire tests on a variety of interior finish materials reported as having been directly involved in high life and property loss fires, based upon eye-witness accounts and/or subsequent studies by fire investigators. The following are condensed descriptions of three field fire comparison tests involving the Steiner Tunnel:

1. February, 1970, Harmar House Convalescent Home fire in Marietta, Ohio; carpeting samples by State Ohio Fire Marshal's office representatives from rooms adjacent to fire area; flame spread classification in excess of 200.

2. April, 1964, Argonaut St. apartment fires in San Francisco, California; decoratively coated untreated plywood paneling samples by Department of Public Works, City of San Francisco representatives from apartment adjacent to units involved in fire or available stock; flame spread classifications 158-173.

3. December, 1961, Hartford Hospital fire in Hartford, Conn.; variety of interior finish materials (including: cellulosic ceiling tile and vinyl wall coverings) samples from undamaged areas of the hospital by representatives of the State of Connecticut, Department of State Police; flame spread values were indicative of the adverse performance during the fire.



In summary, the tunnel test method provides several distinctly advantageous characteristics for classifying the performance of materials under standardized conditions representative of a broad spectrum of fire exposures:

1. A large flaming fire exposure, with ignition energy and area coverage sufficient to bring about progressive surface burning based upon the potential rates-of-release of heat and combustible volatiles characteristic of the materials under evaluation (i.e., flammability measurements by the tunnel test are an inverse function of the critical ignition energy of the material and directly related to the rate-of-heat-release after ignition takes place).
2. A large specimen, nominally 36 sq ft of exposed area, allowing for realistic fire involvement of material surfaces and the development of physical and structural failures (collapse, buckling, large ruptures or cracks, etc.) that may influence flammability performance.
3. A specimen size permitting fire exposure of a wide range of materials, including composite constructions of faced, enclosed or laminated boards, panels, units, or sections in actual field-installed thicknesses, loose fill insulation materials and foamed plastics in thicknesses representative of actual installations.
4. A demonstrated ability to sensitively measure the effects on surface flammability of the density, thickness, surface contour, surface finish, delamination, strength, and joint design of test materials.
5. An ability to characterize high flame spread materials identified as having been involved in rapidly developing field fires (e.g. highly combustible coatings on wood products, certain cellulosic acoustical materials, insulation facings applied with combustible adhesives, etc.), as well as characterization of low flame spread material performance in actual fires (e.g., gypsum and mineral products).

It is recognized that no single test and probably no combination of tests will simulate all actual fire conditions, which may range in intensity from a match flame to a conflagration. Actual fire conditions are possible which will promote involvement of all materials, regardless of the characteristics measured in tests. The tunnel test provides valuable test information applicable to a wide spectrum of fire exposures.

## APPENDIX 6

Engineering Analysis of Existing Flammability Standards  
and  
Test Methods for Cellulose Insulation

Paul Lancer, ESEM

December 12, 1977

Introduction

The purpose of this paper is to analyze existing flammability standards (or test methods) for cellulose insulation. As directed by the Commissioners in their decision concerning Petition CP 77-1, this engineering analysis includes the development of theoretical information on relevant existing standards and the recently developed NBS test methods.

It has been brought to our attention that there have been reported outbreaks of fires where this type material was the first item to be ignited. Some of these fires occurred in house attics. Although there are existing voluntary fire performance standards along with building codes referencing good installation practice for home insulation, particularly around heating appliances and electrical devices, it is unclear at this point to what extent the material and/or improper installation contributed to these ensuing fires.

Much of the fire incident information considered in preparation of this paper is based upon data received from the National Bureau of Standards (NBS). Information from HIA was not available at the time this paper was written, but it will be considered once the information becomes available. Analysis of data on hand indicates that the fire performance properties of cellulose insulation and the method of its installation are interdependent factors in these reported fires. Therefore, any appropriate fire performance standards or test method which may be chosen should simulate or relate to the probable exposure of insulation to energy producing elements or other ignition sources.

Product Definition

At the direction of OPM and OGC, this definition is limited to cellulosic fiber, loose fill, thermal insulation. It does not include spray-on cellulosic insulation. Thermal insulation may be defined as materials or combinations of materials that have air- or gas-filled pockets or void spaces that retard the transfer of heat with reasonable effectiveness under ordinary conditions.

Cellulosic fiber, loose fill, thermal insulation is manufactured predominantly from wood-based cellulosic fiber, such as selected paper (i.e., newspaper, newsprint) or paper board stock, excluding contaminated materials which may adversely affect the performance of the insulation material or the safety of its handling or use. These select paper materials are shredded and ground or pulverized to form the insulation. These pulverized materials may then be treated with suitable chemicals via wet or dry processes to provide improved properties, such as flame resistance. The resulting product is a light, fluffy, fibrous, grayish material that can be poured or blown into place. The insulation may be installed by pouring (by hand) onto attic floors or by blowing (through specially designed pneumatic equipment) between ceiling joists in attics, in stud wall spaces, or other hollow spaces located in housing or other building construction.

Background

Any appropriate standard or test method for measuring the fire performance of any material or product should simulate, directly relate to or mathematically model real life conditions.

A review of epidemiological fire data from NBS<sup>1,2</sup> has revealed the following:

- 
- 1 Memo to Files dated 10/4/77, from D. Gross, Chairman of Task Force on Fire Safety of Insulation.
  - 2 Memo, dated 8/24/77, from B. Buchbinder to D. Gross, Subject: Analysis of Insulation Fire Data.

- (a) Covered electrical (or heating) devices or a wiring hot spot (e.g., short circuit) may cause smoldering ignition of insulation and
- (b) Open flame from a torch or match may cause ignition of exposed insulation in an attic.

Much of these fire data are from incidents which occurred in house attics where recessed light fixtures and short circuits were reported to be sources of ignition. Also, NBS conducted laboratory tests to verify the possibility of fires due to smoldering ignition of the insulation. The tests demonstrated that fires could be initiated (1) by light fixtures where a bulb over the rated wattage for the fixture was used and (2) by electrically overloaded plastic-jacketed wiring covered with thermal insulation<sup>3</sup>.

Given these epidemiological fire data and laboratory test results, the major problems appear to be smoldering combustion and fire spread of cellulose insulation. An appropriate fire performance standard or test method for cellulose insulation should:

- (1) portray the realistic exposure of cellulose insulation to possible ignition source(s),
- (2) address resistance to smoldering combustion (considering ignition sources which generate or dissipate heat over a prolonged period of time),
- (3) address resistance to fire spread (considering open flame ignition sources),
- (4) measure critical flammability variables, such as separability or retention of fire retardants, settled density, moisture absorption, flame resistance permanency, and
- (5) measure the effects of aging on those parameters listed in (4) above.

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<sup>3</sup> Gross, op. cit.

Existing Standards or Test Methods

The following includes a brief description and/or history as well as the corresponding applicability of each existing standard or test method to measure fire performance of cellulose insulation.

Steiner Tunnel Test

At present the Steiner Tunnel Test is the most widely referenced flammability test method for evaluating the surface burning characteristics of building materials, including cellulose insulation. This test was developed and published by Underwriters' Laboratories shortly after World War II and is referred to as UL 723 - Test Method for Fire Hazard Classification of Building Materials. It has since been adopted and recognized as a standard test method for insulation in the following documents.

- (1) American Society for Testing and Materials (ASTM E-84-77a), "Standard Test Method for Surface Burning Characteristics of Building Materials"
- (2) General Services Administration (GSA Federal Specification HH-I-515C), April 13, 1976, "Insulation Thermal (Loose Fill for Pneumatic or Poured Application): Cellulosic or Wood Fiber"
- (3) National Cellulose Insulation Manufacturers Association (NCIMA N-101-73), "Standard Specification for Cellulosic Fiber (Wood Base) Loose Fill Thermal Insulation"
- (4) Underwriters' Laboratories of Canada (ULC-S102-1977), "Standard Method of Test for Surface Burning Characteristics of Building Materials" and
- (5) National Fire Protection Association (NFPA No. 255), May 1972, "Method of Test of Surface Burning Characteristics of Building Materials"

It has also been adopted by all four of the model building codes and is used by most regional and local code authorities.

The "tunnel" may simply be described as a fire test chamber. It is a 25 foot long rectangular duct-shaped insulated enclosure lined with fire brick on the floor



and walls, having a front wall containing a series of viewing windows, and utilizing a test specimen attached to or supported from the underside of the insulated, removable tunnel top. During actual testing two gas burners located at one end of the tunnel deliver flames upward against the surface of the test specimen; also, an air draft is induced.

Originally developed as a means for determining the fire hazard classification of building materials, particularly interior finish materials for walls and ceilings, the tunnel test provides a basis for comparing the surface burning characteristics of materials/products. These characteristics or "subset classifications" are flame spread, fuel contributed, and smoke density. The three subset classifications are each expressed numerically and are dimensionless; there is not necessarily a relationship between these classifications. Two conventional materials - asbestos-cement board and red oak flooring - are used as reference materials. Asbestos-cement board is rated zero or "noncombustible" and red oak flooring is rated 100. The red oak floor rating does not represent an upper-limit value. It is important to note, however, that the measurement of these surface burning characteristics describes flammability properties of materials/products under controlled laboratory conditions and may not describe the fire hazard of materials/products under actual fire conditions.

Although the Steiner Tunnel Test has been widely accepted and referenced for fire testing of cellulose insulation, there are several problems related to its adequacy as a tool for measuring the fire hazard for cellulose insulation. These problems are listed below.

(1) The most quoted surface burning characteristic for cellulose insulation is flame spread. The flame spread over a material depends upon environmental conditions which include the incident heat flux and temperature, oxygen concentration, and the air velocity/turbulence passing over its surface. Since these parameters have not been studied in detail, the meaningfulness of the flame spread classification (or FSC) is questionable.

(2) Materials with a low FSC equal to or less than 25 have generally been regarded by the building codes as providing a high degree of safety. However, the rating of 25 does not fully describe how the material performed under controlled laboratory conditions; it does not necessarily represent a

uniform rate at which flames spread but only the distance flames travelled during a time interval.

Therefore, the potential in real life situations for rapid flame spread of some low FSC materials is not sufficiently stated by the FSC only. Perhaps, an initial and an average rate of flame spread would supply more meaningful data.

(3) The specified ignition source is a test flame extending downstream to a distance of 4 1/2 feet over the specimen surface; the ignition source encompasses an area typical of a wall exposed to a fire in a large waste container or a small upholstered chair. The ignition source does not simulate the exposure from a small open flame or a smoldering ignition source, such as recessed light fixtures or electrical wiring.

(4) The aforementioned ignition source is projected upward toward a ceiling mounted and supported loose-fill material specimen. This testing configuration may not relate to several real life accident patterns as identified in the epidemiological fire data.

(5) Recent tests by NBS of home insulation materials installed in a simulated attic demonstrate that when installed on the floor and subjected to 160° F preheating to simulate a hot summer attic, some material which is rated 25 or less (a good tunnel rating) will burn readily if subjected to an ignition source. This additional information again suggests an inadequacy of the tunnel test for measuring the burning characteristics of home insulation products.

(6) The results of the tunnel test are expressed as a flame spread rating. This means that the test is designed to measure how quickly a given material will burn. In the present case the test is being considered as a test to measure the burning characteristics of a product which will be installed on the floor of an isolated part of an individual's home.

X 4 Memo to Files, dated 11/28/77, from Bernard Schwartz, ESEM, on Fire test of home insulation.

If a fire occurs, it is likely to happen when there is no one in the attic, and the fire can be expected to burn undetected for some length of time or until it reaches full involvement of the attic. In view of these events, it may be more appropriate to have a test procedure which measures if and to what extent a material burns rather than how quickly a material burns.

(7) Before the actual fire test is conducted, the specimen is conditioned to a constant weight at 70°F and 35 to 40% relative humidity. These conditions may not adequately simulate the varied environmental conditions to which insulation will be subjected during its existence as a useable product nor does this standard test method consider the effects of other pre-conditioning techniques on the flame spread classification.

The Steiner Tunnel Test, as previously stated, is widely accepted and referenced as a means of measuring fire exposure behavior for building materials. Nevertheless, as a comprehensive fire safety performance test, the "tunnel" should simulate what has been determined as the most probable fire scenario(s) and should measure the most significant fire parameter(s). Overall, the "tunnel" appears inappropriate for measuring or simulating these types of fire occurrences primarily because of the configuration of the specimen, size or magnitude of the ignition source, and the flammability properties measured. However, the tunnel may be appropriate for measuring fire exposure behavior of ceiling materials or materials sprayed or placed on ceilings.

NOTE: The following two standards which reference the Steiner Tunnel Test include ranges for surface burning characteristics in connection with fire performance of loose fill cellulose thermal insulation. The other three groups (ASTM, ULC, NFPA) listed above only reference the test method.

Federal Specification - HH-I-515C (April 13, 1976): "Insulation Thermal (Loose Fill for Pneumatic or Poured Application): Cellulosic or Wood Fiber"

This standard classifies loose fill (pneumatically applied or poured) cellulose insulation according to its surface burning characteristics. It states that a Class 25 material has a FSC equal to or less than 25. A Class 50 material has a FSC greater than 25 but less than 50 and a smoke developed rating less than or equal to 50.

NCIMA N-101-73: "Standard Specification for Cellulose Fiber (Wood Base) Loose Fill Thermal Insulation".

This standard classifies material by type depending upon its surface burning characteristics. A Type I material is one which has a FSC equal to or less than 25 and smoke developed and fuel contributed classifications less than or equal to 50. A Type II material is one which has a FSC greater than 25 but less than 75 and smoke developed and fuel contributed classifications less than or equal to 50.

The NCIMA standard also lists tests for flame resistance permanency and moisture absorption physical requirements. These parameters may be interrelated and may be chosen as a measure of how the fire performance of a material may vary after being subjected to accelerated aging and high temperature and high humidity conditions, respectively. Acceptable flame resistance permanency constitutes no change in flame spread classification after the insulation has been subjected to an accelerated aging procedure. Acceptable moisture absorption constitutes weight gain not exceeding 15 percent.

Testing for each of these physical requirements is listed in ASTM C 739-73 (Standard Specification for Cellulosic Fiber (Wood-base) Loose-fill Thermal Insulation) also. The test for flame resistance permanency references the use of a 2-foot tunnel as more or less a quality control tool or preliminary screening test to observe and measure the flame spread behavior of conditioned versus aged insulation. The use of such a preliminary screening procedure seems to imply there is a direct correlation of the calculated flame spread classification between the Steiner tunnel and the 2-foot tunnel apparatus even though a footnote specifically qualifies that there is none. This footnote further references the article in which a detailed description, including construction drawings, of this 2-foot tunnel apparatus was given. This use of the 2-foot tunnel as detailed in this article only examined its applicability for rigid, relatively flat material or material capable of being applied on such a surface and even suggested a correlation formula relating its flame spread rating to the Steiner tunnel FSC. Therefore, it is questionable whether loose fill insulation is an appropriate material to be evaluated with this 2-foot tunnel apparatus.

*But does failure of 2' tunnel test = likely to fail SFT?*

Furthermore, the accelerated aging in the flame resistance permanency procedure and the conditioning in the moisture absorption procedure may not adequately consider the environmental conditions to which the insulation may be exposed during use, such as the short and long term affects of temperature and humidity extremes on these physical requirements. Also, the moisture absorption procedure does not specify the specimen configuration.

Proposed Federal Specification HH-I-515D draft dated November 4, 1977- for "Insulation Thermal (Loose Fill for Pneumatic or Poured Application): Cellulosic or Wood Fiber"

This Federal Specification, if adopted, will supersede HH-I-515C. It references two new test methods for evaluating the fire performance of cellulose insulation in place of the ASTM E-84 Steiner Tunnel Test. These new tests are referred to as the "Attic Floor Radiant Panel Test" and the "Smoldering Combustion Test".

The "Attic Floor Radiant Panel Test" may be described as a procedure for measuring the sensitivity to flame spread of insulation installed on the floor of a building attic. The sensitivity parameter selected was the critical radiant flux. This parameter is a quantitative measure of the ease with which flame propagation may occur on the surface of the test material in a designed test configuration. In short, insulation, of a specified thickness, installed in a long tray is subjected to a flaming ignition source in a graded radiant heat energy environment in a test chamber. This graded radiant heat energy environment depicts thermal radiation levels likely to impinge on the floor of an attic exposed to heat from solar radiation and an open flame ignition source. Therefore, the conditions of this test simulate the configuration and radiant heat exposure which may be experienced by insulation laid between attic floor joists and subjected to a small open flame ignition source. The test is used to measure the heat flux at which the insulation will no longer propagate flame under the test conditions. This provision of the draft standard specifies that materials tested shall have a critical radiant flux equal to or greater than 0.12 watts per square centimeter.



The "Smoldering Combustion Test" may be described as a procedure for measuring the tendency of insulation to support and propagate smoldering combustion when subjected to a smoldering ignition source (a lit cigarette). The parameters selected were the extent of damage to the insulation specimen, and any observable combustion behavior, such as flaming. In short, a lighted cigarette is inserted vertically, with its lit end upward, into the center of an insulation specimen installed in an 8 in. square open-top metal box (specimen holder) at the density and in the physical state of the material in its intended use. A lit cigarette may correlate with a typical ignition source, such as an overheated recessed lighting fixture, which may contact insulation installed in residential occupancies. This provision of the draft standard specifies that materials tested shall show no evidence of flaming combustion, nor charring within 4 centimeters of the sides of the specimen holder, nor lose in excess of 15 percent of its initial weight.

These new test methods appear to be appropriate for addressing some of the fire hazards previously noted because both open flame and smoldering ignition sources have been specified along with attempting to simulate real life conditions. However, this standard does not measure the effects of changes in density or of preheating specimens on critical radiant flux or on smoldering combustion results, nor includes provisions for flame resistance permanency, effects of aging and the separation of fire retardant chemicals from the insulation matrix. There also may be a need to review (1) the requirements of draft-protection versus draft-controlled conditions which may be more realistic of air patterns in house attics and (2) correlation of a lit cigarette with epidemiologically identified smoldering ignition sources. Also, the moisture absorption requirement references the ASTM C 739-73 procedure, which was previously discussed above in terms of its relation to real life conditions.

Proposed Canadian Government Specifications Board Provisional Standard 51-GP-60P, draft dated January 1977, for "Thermal Insulation, Cellulose Fibre, Loose Fill"

This Canadian draft standard references the use of the Steiner tunnel apparatus as a means for measuring the fire performance of loose fill cellulose thermal insulation. The flammability characterization parameter selected was the surface burning characteristic of flame spread. The standard,

furthermore, states that prior to February 1, 1978, loose fill cellulose thermal insulation be tested in accordance with the current version of ASTM E-84 or ULC-S102-1977, but taking into account a correction factor for the wire mesh supporting screen when determining flame spread ratings. Previous comments in this document relative to the Steiner tunnel apparatus and test also apply in this case.

However, after February 1, 1978, this standard requires that this insulation material be tested in accordance with ULC-S102.2-1977, entitled "Standard Method of Test for Surface Burning Characteristics of Flooring, Floor Covering and Miscellaneous Materials". ULC-S102.2-1977 may simply be described as a modified version of the Steiner Tunnel Test. Basically this modified standard may be appropriate for those materials which cannot be conveniently tested in a ceiling mounting configuration, such as loose fill materials. The major difference between the modified tunnel test and the Steiner Tunnel Test is that loose fill material is placed on asbestos paper located on the floor of the tunnel. The gas burners then project downward toward the material surface at a 45 degree angle.

When tested as specified in either ULC-S102-1977 or ULC-S102.2-1977, the flame spread classification shall not exceed 35.

This Canadian draft standard only addresses open flame ignition and does not consider smoldering ignition sources, such as heating appliances or electrical equipment. There are problems concerning the use of the same gas burners as referenced in the traditional Steiner Tunnel Test because of the magnitude of the ignition source and because the preheating of the sample before the actual test may not be sufficient. The flame resistance permanency procedure references ASTM C 739-73; this provision in the ASTM standard has been previously discussed. A moisture absorption procedure has been devised which may or may not simulate accurate conditioning for determining expected moisture uptake for a short or long term aging exposure. Furthermore, there is no specified limit on an allowable percentage for moisture absorption. It should also be noted that a provision for measuring separation of chemicals is under development.

National Mineral Wool Insulation Association (NMWIA)  
Proposed Test Method for "Localized Heat Sources and Their  
Effect on Loose Fill Thermal Insulation"

In April 1977, the Fire/Safety Committee of the NMWIA submitted to ASTM Committee E-5 (on Fire Tests of Materials and Construction) a draft of this test method. Basically this test method consists of installing preconditioned loose fill insulation into a temperature- and draft-controlled attic section containing representative house wiring and/or heat sources, such as light bulbs or recessed light fixtures. The test method is a realistic attempt to simulate installation techniques, aging of insulation, and temperature/air conditions found in the attic. The parameters selected to evaluate the fire performance of loose fill insulation consist of measuring the temperature rise at various points at and away from the heat sources and observing and noting any physical changes within the insulation, such as smoldering, discoloration, charring, shrinkage, or flaming.

This test method only addresses smoldering combustion of attic installed insulation caused by household heat sources or electrical fixtures. It does not address open flame ignition of insulation nor smoldering combustion which may occur in walls of homes. There, also, are no specific references for effects of settled density and preheating specimens on fire performance, flame resistance permanency, nor separation of chemicals.

#### Conclusions

Since the fire problem associated with cellulose insulation generally appears to be smoldering combustion and fire spread, any appropriate standard or test method and criteria should realistically portray and thereby minimize the occurrence of fires associated with this product.

## **An Investigation of the Fire Environment in the ASTM E 84 Tunnel Test**

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Issued August 1977

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## NOMENCLATURE

C	Heat capacity of air
d	Maximum distance of flame travel beyond the end of the burner flame
D	Hydraulic diameter = 4 times the cross sectional area divided by the perimeter
E	Ratio of eddy diffusivities for heat and momentum
f	Friction factor for the tunnel surface
FC	Fuel contribution classification
FSC	Flame spread classification
G	Mass flow rate
h	Surface heat transfer coefficient
H	Total incident heat flux
H <sub>c</sub>	Convective component of the heat flux
K	Thermal conductivity
L	Length
ΔP	Pressure difference
q	Heat release rate per unit area
Q	Total rate of heat production in the tunnel
Q <sub>B</sub>	Rate of heat production from the burner
Q <sub>L</sub>	Total rate of heat loss in the tunnel
S	Number of volumes of oxygen required for the complete combustion of one volume of fuel
SDC	Smoke development classification
t	Time
T	Absolute temperature
T <sub>O</sub>	Ambient absolute temperature
T <sub>S</sub>	Absolute temperature of the exposed face of the specimen
T <sub>R</sub>	Absolute temperature of the back face of the specimen
ΔT	Temperature difference
V	Air velocity
V <sub>a</sub>	Volumetric flow rate of air
V <sub>g</sub>	Volumetric flow rate of gas
x	Thickness of specimen
Y	Oxygen concentration in the tunnel
Y <sub>O</sub>	Oxygen concentration of normal air (20.8 percent)



## NOMENCLATURE (cont'd)

$\epsilon$	Emittance of specimen surface
$\phi$	Oxygen depletion = $\frac{Y_o - Y}{Y_o} \times 100$ percent
$\phi_B$	Oxygen depletion in duct due to regular burner only
$\rho$	Air density
$\sigma$	Stefan Boltzmann constant
$\nu$	Kinematic viscosity

## ABBREVIATIONS

ACB	Asbestos Cement Board
AMB	Asbestos Millboard
ASTM	American Society for Testing and Materials
NBS	National Bureau of Standards
UL	Underwriters' Laboratories

## CONVERSION OF UNITS

1 Btu	= 1.054 kJ
1 Btu/s	= 1.054 kW
1 Btu/ft <sup>2</sup> s	= 1.14 W/cm <sup>2</sup>
1 ft	= 0.305 m
1 in	= 25.4 mm
1 mil	= 25.4 $\mu$ m
1 cfm	= 0.473 dm <sup>3</sup> /s = 0.473 l/s
1 cfh	= 7.88 cm <sup>3</sup> /s
1 lb	= 0.454 kg
1 lbf	= 4.45 N
1 in of water	= 249 Pa
1 °F	= 0.555 °C
T (°F)	= 1.8 T (°C) + 32

## AN INVESTIGATION OF THE FIRE ENVIRONMENT IN THE ASTM E 84 TUNNEL TEST

William J. Parker

Measurements were made of heat flux, oxygen concentration, temperature, velocity and pressure in a series of instrumented ASTM E 84 tunnel tests using (1) standard length specimens, (2) 0.91-m (3-ft) long specimens, and (3) a reference specimen consisting of asbestos-cement board and an auxiliary controlled supply of methane. Five different flow rates of methane to the auxiliary burner provided constant and known heat inputs simulating the gaseous decomposition products from regular test specimens. Incident heat fluxes on an inert specimen surface as high as  $6.3 \text{ W/cm}^2$  ( $5.5 \text{ Btu/ft}^2 \cdot \text{s}$ ) were measured within the flame impingement zone with a water-cooled heat flux meter 0.61 m (2 ft) downstream from the burner. While oxygen depletion in the tunnel did not appear to be a dominating factor in controlling the flame spread, the oxygen depletion measured in the exhaust duct beyond the tunnel correlated with the total rate of heat production of the specimens. It appears that the differences in the observed burning behavior of materials in the tunnel test and in a room may be mainly due to differences in the incident heat flux distribution in the two cases. These distributions reflect the different geometries, orientations, and ignition sources. The potential for rapid flame spread of some low flame spread classification (FSC) low density materials is evident from observations of the flame propagation along these materials during the tunnel test, but is not adequately reflected in the flame spread classification.

Key words: ASTM E 84; fire tests; flame spread; heat flux; heat release rate; smoke; Steiner Tunnel Test; oxygen depletion.

## 1. INTRODUCTION

## 1.1. General

Prior to 1950 fire protection of buildings dealt primarily with (1) the prevention of fire, (2) early detection and warning, (3) confinement with fire resistant structural components (e.g. walls, partitions, floors, ceilings, doors, etc.), and (4) extinguishment. Major fires which spread rapidly along interior surfaces causing large property losses and high death tolls due to the effects of smoke and toxic gases alerted the fire protection community to the need for a test which could be used to regulate interior finish materials with respect to their burning characteristics (e.g. flame spread, heat release, and smoke production).

The tunnel test was originally developed at Underwriters' Laboratories (UL) by A. J. Steiner for determining the fire hazard classification of building materials [1]<sup>1</sup>.

<sup>1</sup> Numbers in brackets refer to the literature references listed at the end of this paper.

The three classifications determined in the Steiner tunnel are flame spread, fuel contribution, and smoke production. The first formal test standard (UL 723) was published by UL in 1950 with revised editions in 1958, 1960, and 1971. The test was adopted by the American Society for Testing and Materials (ASTM) as a tentative standard (E 84) in 1950 and formally adopted in 1961 with revised editions in 1960, 1970, and 1972. It was adopted as a standard of the National Fire Protection Association (NFPA No. 255) in 1955 with revised editions in 1958, 1961, 1966, 1969, and 1972. It was approved as an American National Standard (A 2.5) by the American National Standards Institute (ANSI) in 1963 with a revised edition in 1970. The tunnel test has been adopted by all four of the model building codes and is used by regional and local code authorities.

Prior to 1960 the tunnel test was used primarily for the evaluation of the surface burning characteristics of interior finish materials for walls and ceilings. In the late 1960's an appendix entitled, "Guide to Mounting Methods" was added to the Standard to permit the testing of materials which were not self-supporting. These materials include acoustical panels, adhesives, cementitious mixtures, sprayed fiber, batt or blanket insulation, loose fill insulation, coatings, piping, floor coverings, etc.

The tunnel test has thus been used to examine a large range of materials with a specimen area of sufficient size to include joints and other construction details and to be affected by delaminations and deformations which might be expected to occur in an actual fire. The 7.3-m (24-ft) long specimen which forms the ceiling surface of the tunnel has an exposed width of 0.46 m (1.5 ft) and is exposed to a 1.4-m (4.5-ft) long igniting flame with a total heat release rate of 88 kJ/s (5000 Btu/min) based on the gross heat of combustion of methane. The tunnel is lined on the floor and walls with fire brick. The igniting flame, which covers approximately 0.65 m<sup>2</sup> (7 ft<sup>2</sup>) of the specimen surface, is of an area that might typically be encountered by a wall exposed to a fire in a large waste container or a small upholstered chair. Air at a velocity preset prior to test at 1.2 m/s (240 ft/min) is drawn through the tunnel by means of a fan at the exhaust end.

## 1.2. Hazard Classification and Reproducibility

The flame spread classification described and used in this report is based on ASTM E 84-70 which was in effect at the time of this research. The three classifications derived in the tunnel test are each expressed on a scale which rates red oak flooring as 100 and asbestos-cement board, which is noncombustible, as zero. 1) The flame spread classification (FSC) is based on the time required for the flame to progress beyond the end of the tunnel or on the maximum distance reached during the 10-minute exposure period if the flame fails to reach the end. 2) The fuel contribution (FC) is based on the area under the temperature versus time curve over the 10-minute exposure period for the thermocouple located in the hot combustion product laden air 0.31 m (1 ft) upstream from the vent end of the tunnel and 2.5 cm (1 in) below the surface of the specimen. 3) The smoke development classification (SDC) is

based on the area under the light absorption versus time curve over the 10-minute exposure period measured by the smoke meter located in the duct some distance beyond the end of the tunnel.

Concern over the reproducibility of the test led Endicott and Bowhay [2] to perform a statistical evaluation of the effect of relative humidity, draft velocity, brick temperature, section length, specimen thickness, and preheat time on the three hazard classifications. The two materials used in this evaluation were Douglas fir plywood and particle board. The FSC was found to depend strongly on moisture content, brick temperature, preheat time, and specimen thickness, but had no significant dependence on draft velocity. On the other hand the smoke classification was highly dependent on velocity. However, the velocity was only varied between 1.17 and 1.27 m/s (230 and 250 ft/min).

While the above evaluation was performed by varying the test conditions on a single tunnel, Lee and Huggett [3] performed an interlaboratory evaluation involving nine materials and eleven tunnels each utilizing its normal operating conditions. For a series of eight specimens, the maximum coefficient of variation between laboratories was 43% for flame spread, 85% for smoke, and 117% for fuel contribution. These variations were due to differences in tunnel construction and in the operating procedure and illustrated a need to tighten up the standard to minimize these differences.

Changes in the standard are considered by the tunnel operators through the ASTM subcommittee E05.04. A new procedure for determining the FSC has been included in ASTM E 84-76a.

### 1.3. Comparison with Corner and Room Fire Tests

The evaluations described above dealt with the reproducibility of the fire hazard classifications measured by the tunnel test. They did not address the question as to the applicability of the classification to the growth of fires in rooms. Materials with  $FSC \leq 25$  have generally been regarded by the building codes as providing a high degree of fire safety. Serious fires involving cellular plastics of undetermined FSC and demonstrations of rapid and extensive fire buildup in corners involving some low FSC cellular plastics at the University of California at Berkeley [4] and at Factory Mutual [5] have raised concern as to the applicability of the test for these materials.

The question of the applicability of the FSC of an interior finish material to its potential hazard in a full-scale fire was investigated by UL [6] in a series of vertical panel, open corner, corridor and room fire tests involving 31 different building materials whose FSC was measured in the tunnel and five different size ignition sources. Most of the experiments were performed with 9.1-kg (20-lb) wood cribs in the open corner configuration. Under these conditions the extent of the fire buildup in the open corner tests was roughly correlated with the FSC for the whole range of materials, but the rapidity of the fire buildup depended more on the density of the material than on its FSC. The results of the limited number of room fire tests indicated that a 9.1-kg (20-lb) wood crib, which is roughly equivalent in burning rate to

a small upholstered chair or a large waste container was a sufficiently large ignition source to cause full involvement of a  $2.4 \times 3.7 \times 2.4$  m ( $8 \times 12 \times 8$  ft) room lined with a FSC  $\leq 25$  material. When the material was a low density foam plastic, this buildup time was of the order of a minute and a half. It thus appears that an FSC  $\leq 25$  is no assurance that a surface finish material is safe to use in a critical location. These low density materials are particularly serious because of their short buildup time to full room involvement. In the UL tests [6] a FSC 22 low density,  $37 \text{ kg/m}^3$  ( $2.3 \text{ lb/ft}^3$ ), cellular plastic caused full involvement of a room in one-third of the time required for a FSC 178 medium density,  $527 \text{ kg/m}^3$  ( $31 \text{ lb/ft}^3$ ), cellulosic. Full involvement occurred in one minute and 20 seconds for the low density material and four minutes and 20 seconds for the medium density material. Since a FSC 22 material has a maximum flame spread distance of only 2.7 m (9 ft) in the tunnel it is natural to inquire about differences in burning behavior between the tunnel and the room. It is also desirable to see if there are differences in burning behavior between cellulose and plastics in the tunnel. Clearly there is a need for analytical models for flame spread in the tunnel and in the room to provide guidance in the utilization of the tunnel data. The flame spread along a material depends on its environmental conditions which include the incident heat flux and the temperature, oxygen concentration, and the velocity of the air passing over its surface. There have been no extensive measurements made on the environment in the tunnel.

#### 1.4. Diagnostic Measurements in the Tunnel

The present investigation was concerned with the characterization of the environment in the tunnel and with discovering significant elements of the burning behavior which could serve as a basis for establishing an analytical model for flame spread in the tunnel.

Recent measurements have also been reported by Quintiere and Raines [7] on the variation in the air velocity at the entrance to the tunnel during the test and some internal temperature distributions from which the heat losses along the tunnel could be deduced. These measurements were carried out on four different carpets in the Hardwood Plywood Manufacturer's Association tunnel in Arlington, Virginia. Maximum drops in the inlet air velocity during the tests ranged from 19 to 28 percent for the different materials tested. Approximately half of the heat produced by the burner flame was absorbed by the specimen or lost within the tunnel.

The data presented in this report came from seven groups of instrumented tunnel tests spaced approximately a month apart. Each group consisted of up to 20 tests which took two days to set up and run. The tests were conducted at Underwriters' Laboratories in Northbrook, Illinois and include air velocity, temperature, heat flux, oxygen concentration, pressure drop and specimen weight loss as well as the customary flame distance and smoke measurements. Although a large range of interior finish and insulation materials were included in this program, materials which would cause additional problems because of their melting and dripping during the test were excluded.



The nomenclature appears in the front of this paper (see page viii) and the property data used in the calculations are listed in table 1. This research project was undertaken during 1974 when the author participated in an NBS-UL scientific exchange program. The description of equipment and procedures in this report were current at the time of the research.

Table 1. Property Data Used in the Calculations

	Engineering Units	S.I. Units
Density		
Air 15 °C (60 °F)	0.0763 lbs/ft <sup>3</sup>	1.22 kg/m <sup>3</sup>
40 °C (105 °F)	0.0702 lbs/ft <sup>3</sup>	1.12 kg/m <sup>3</sup>
Heat Capacity		
Air 15 °C (60 °F)	0.24 Btu/lb °F	1.0 kJ/kg K
Air (average between 15 °C (60 °F) and 816 °C (1500 °F))	0.26 Btu/lb °F	1.09 kJ/kg K
Thermal Conductivity		
Asbestos Millboard	$2.17 \times 10^{-5}$ Btu/ft °F	0.135 W/m K
Asbestos-Cement Board	$5.8 \times 10^{-5}$ Btu/ft °F	0.36 W/m K
Heat of Combustion		
Methane gross 15 °C (60 °F)	1012 Btu/ft <sup>3</sup>	39 J/cm <sup>3</sup>
Methane net 15 °C (60 °F)	912 Btu/ft <sup>3</sup>	34 J/cm <sup>3</sup>
Kinematic Viscosity		
Air 15 °C (60 °F)	$1.6 \times 10^{-4}$ ft <sup>2</sup> /sec	15 mm <sup>2</sup> /s
Heat of Vaporization		
Water	1072 Btu/lb	2.49 kJ/g

## 2. DESCRIPTION OF ASTM E 84 TUNNEL TEST METHOD

### 2.1. Test Apparatus

The Steiner tunnel was developed at the Underwriters' Laboratories and is described in the ASTM book of fire test methods [8] and in the Underwriters' Laboratories standard UL 723. Nevertheless, a brief description of the instrument and its operation may be of value here in order to stress those elements which are most important to the present study. Furthermore, there are slight ambiguities in the write-up of the standard test, such that operational procedures can vary unless agreed upon by the different operators using the tunnel.

Basically, the instrument as used at the Underwriters' Laboratories in Northbrook is a steel duct-shaped enclosure 8.7 m (28.5 ft) long lined with fire brick on the floor and walls to provide a cross section  $0.44 \pm 0.01$  m ( $17.5 \pm 1/2$  in) wide and  $0.3 \pm 0.01$  m ( $12 \pm 1/2$  in) high. The front wall contains a series of viewing windows. (Refer to figures 1 and 2 for more details.) The specimen forms the ceiling closure

over the final 7.3 m (24 ft). The specimen is preceded by a 0.3-m (1-ft) section of 6.4-mm (1/4-in) thick asbestos-cement board (ACB). The other 1.1-m (3.5-ft) section is permanently closed by the steel shell. The 25-ft steel lid, which is lined with 51-mm (2-in) thick calcium silicate insulation over 6.4-mm (1/4-in) thick ACB, is closed in contact with the top of the specimen. The enclosure is rendered air-tight with a water seal. Methane gas is introduced through two nominal one-inch pipe burners spaced 0.2 m (8 in) apart along a line normal to the airflow. The pipes extend 0.11 m (4.5 in) above the floor, 7.3 m (24 ft) from the end of the tunnel. These burners provide the diffusion flames to expose the first 1.4 m (4.5 ft) of the specimen. All axial distances in the tunnel which are quoted in this report are measured downstream from these burners.

The air is admitted at the floor level of the tunnel through a 0.44-m (17.5-in) long slit with an adjustable height located 1.4 m (4.5 ft) ahead of the burner. The other end of the tunnel terminates in a circular exhaust duct 0.41 m (16 in) in diameter. Just beyond the tunnel the duct takes an upward turn and then a horizontal bend in order to run horizontal at right angles to the tunnel and 1.2 m (4 ft) above it. The duct terminates in a 0.6-m (2-ft) diameter stack with a fan at its base to provide the suction necessary to pull air through the tunnel. The negative pressure at a tap located in the duct approximately 6.7 m (22 ft) from the end of the tunnel is held constant by an automatic damper located downstream. There is a vertical path smoke meter located just ahead of the damper. There is a thermocouple located 25 mm (1 in) below the specimen at 7.0 m (23 ft) from the burner which provides the data for the fuel contribution index. There is a buried thermocouple 3.2 mm (1/8-in) below the surface of the floor of the tunnel at 4.3 m (14 ft) that is used to establish the starting temperature for each test.

## 2.2. Operation

Prior to test, the average air velocity is measured with a thermal anemometer at seven points across the width of the tunnel along the midheight 7.0 m (23 ft) beyond the burner. The velocity can be varied by changing the negative pressure at the pressure tap or by changing the height of the entrance slit. However, once these settings were established to get an average air velocity of 1.2 m/s (240 ft/min) with the tunnel preheated to 41 °C (105 °F), they have been fixed at a negative pressure drop of 18 Pa (0.072 in of water) and a slit height of 83 mm (3.25 in). With a methane flow to the burner of 2.3 dm<sup>3</sup>/s (4.9 cfm), corresponding to  $8.8 \times 10^4$  J/s (5000 Btu/min) (using the gross heat of combustion), red oak spreads flame past the end of the tunnel in approximately 5.5 minutes. The gas flow rate to the burner is measured by the difference in gas meter readings over the duration of the test.

Calibration runs are conducted approximately once a month to check the air velocity and the time at which flame passes over the end of the tunnel for red oak. Significant departures from the normal lead to trouble shooting rather than to the readjustment of the pressure, slit height, or gas flow which remain as fixed parameters of this tunnel. Leaks in the tunnel are sometimes found and repaired during this calibration process.

The time of flameover of the oak also depends on the degree of turbulence developed in the tunnel. Changes in tunnel construction through the years such as using flush rather than recessed viewing windows have caused a reduction in the turbulence which resulted in a corresponding reduction in flame spread. Five bricks have been placed on the floor of the tunnel at strategic locations to increase the degree of turbulence to the point that the red oak flamed over once again at 5.5 minutes. The location of these bricks are now fixed at 1.4, 2.3, 3.5, 5.0, and 5.9 m (4.5, 7.5, 11.5, 16.5 and 19.5 ft) from the burner. Their positions are alternated between the front and rear walls and they protrude into the tunnel 50 mm (2 in) horizontally and 200 mm (8 in) vertically.

The cold tunnel is preheated to 66 °C (150 °F) and then cooled to 43 °C (110 °F), as indicated by the buried thermocouple at 4.3 m (14 ft), before a specimen is inserted. The burner must be turned on and the test started while this temperature lies between 38 °C (100 °F) and 43 °C (110 °F). This may require heating or cooling between tests. The nominal starting temperature is taken to be 41 °C (105 °F). The windows are cleaned as necessary between tests and high temperature burnouts are conducted when the tunnel accumulates deposits such as those from dripping specimens.

The tunnel is operated by a technician who loads the specimen and electrically ignites a pilot flame which in turn ignites the burner gas when it is turned on. The gas meter reading is recorded before and after the test. A timer is started at the instant of ignition of the burner gas. The technician, records the time of ignition of the specimen for particular tests and monitors the pressure during all tests. The actual control of the pressure, and thus the airflow, through the tunnel is by means of the automatic damper in the duct. The temperature of the fuel contribution thermocouple and the light transmission through the smoke are recorded on a strip chart recorder. The technician records the times at which the engineer observes, through the observation ports, that the flame has reached various distances in the tunnel. The distance is reported to the nearest 0.15 m (0.5 ft).

The reading of the flame distance is done by trained personnel. This requires some judgment since much of the time the end of the flame is composed of brief flashes and detached flamelets. The observation can also be complicated by obscuration of the viewing ports by smoke from some materials. Although there is no written definition of what constitutes flame length, it is probably best defined as the distance at which there is flame present approximately one-half of the time over a time interval of several seconds. As will be brought out later, the reported flame distance appears to coincide with an abrupt decrease in the extent of the damage to the specimen.

### 2.3. Classification

At the time of the research the FSC was calculated from one of four formulas depending on how soon the flame reaches the end of the tunnel or where the flame stops within the tunnel. 1) If the flame spreads over in 5.5 minutes or less, the  $FSC = 550/t$  where  $t$  is in minutes. This gives red oak which is the reference standard a FSC 100.

2) If the flame spreads over within the 10-minute test period, but takes greater than 5.5 minutes, the  $FSC = 50 + 275/t$ . 3) If the flame stops between 5.5 m (18 ft) and the end of the tunnel, the  $FSC = 50 + 4.62 d$  where  $d$  is the maximum distance in meters traveled beyond the burner flame whose designated distance is 1.4 m (4.5 ft). 4) If the flame stops at 5.5 m (18 ft) (4.1 m (13.5 ft) past the burner flame) or less, the  $FSC = 16.7 d$ .

An important discontinuity was noted in this calculation procedure. If the flame were to spread to a point just short of the end of the tunnel in 0.55 minutes, the  $FSC = 77.5$ . If it passes over in the same time,  $FSC = 1000$ . Both situations could occur in the case of duplicate runs of the same material. A new calculational method in which the  $FSC$  is proportional to the area under a modified flame distance versus time curve has been included in ASTM E 84-76a to resolve this discontinuity.

### 3. INSTRUMENTATION

#### 3.1. General

During the course of this project seven groups of instrumented tunnel tests were performed in order to establish the environment in the tunnel. Although the operation of the tunnel was usually the same as it would have been during a normal run, the presence of the monitoring instrumentation obviously had some effect on the environment it was attempting to measure. This instrumentation included pitot tubes, gas sampling tubes, and water-cooled heat flux meters all of which had copper tubing running along the floor of the tunnel and out through the entrance slit. Thermocouple support rods and their lead wires could also have affected the flow pattern. However, the inflow velocity and the times and distances of flame spread in the tunnel did not appear to be affected significantly. Nevertheless, it is well to keep in mind that these disturbances did exist to some degree. There was a drop in the air velocity of about 20%, however, when the rather massive auxiliary burner was added for the experiments described in section 4.2.

#### 3.2. Temperatures

The temperatures in the tunnel were measured with 0.25 mm (10 mil) (#30 gage) Chromel Alumel and 0.25 mm (10 mil) Iron-Constantan thermocouples. Air temperature profiles were obtained at different distances with trees of either ten or twelve thermocouples spaced vertically and held in place on ring stands with high temperature cement. Wall and floor temperatures were measured with similar thermocouples held to the surface of the brick with plaster. The thermocouple leads were run along the floor out through the entrance slit of the tunnel and were connected to a 24-point temperature recorder with a 48-second print cycle (2 seconds between prints). Thermocouples on the exposed surface of the specimen or 25 mm (1 in) below it were mounted by drilling two holes 25 mm (1 in) apart and bringing the lead wires through the specimen and securing them to the unexposed surface. At that point the 0.25 mm (10 mil) wires were generally welded to 1.3 mm (50 mil; #16 gage) wires and then led along the top of the specimen

and back into the tunnel 0.31 m (1 ft) upstream of the burner and out through the slit. The lead wires on either side of the exposed thermocouple junction ran parallel to the specimen surface for 13 mm (1/2 in) in order to minimize heat conduction losses. Selected thermocouples at critical locations were connected to continuous pen recorders in order to obtain a better time response.

Temperature data were also taken with the 1.0 mm (40 mil; #18 gage) chromel alumel thermocouple at 7.0 m (23 ft) which is used to measure the fuel contribution in all of the regular tests.

No corrections to the thermocouple readings were made for radiation.

### 3.3. Oxygen Concentration

The oxygen concentration at various distances in the tunnel and in the exhaust duct was measured with a chemical oxygen cell which uses a KCl solution with gold and zinc electrodes. It has an output voltage which is directly proportional to the oxygen concentration. It nominally produces 180 mv for a 20.8 percent oxygen concentration. However, the output depends on the condition of the cell and decreases with age, requiring rejuvenation in six months or less depending on the usage.

A fiber glass filter was used to remove particulates, a charcoal filter was used to remove organic vapors, a silica gel filter was used to remove water and a pumice filter loaded with sodium hydroxide was used to remove acids. An adjustable flow meter between the cell and the vacuum line was set to produce a flow rate of 39 cm<sup>3</sup>/s (5 cfh) through the cell. The inlet to the series of filters was connected to a 6.4-mm (1/4-in) copper tube whose other end terminated at the sampling point. During the later phases of this project oxygen concentrations were also measured with a high temperature oxygen cell which oxidized any unburned fuel prior to the measurement.

### 3.4. Air Velocity

Velocities of the ambient air were measured with a hot film thermoanemometer and with pitot tubes. The pitot tube system alone was used at the elevated temperatures. The vertical velocity profiles were obtained with a bank of ten pitot tubes mounted on a ring stand. They were connected to a rotary fluid switch by means of 6.4 mm (1/4-in) copper tubing running along the floor of the tunnel and out through the entrance slit. This switch was used to connect the pitot tubes in sequence to the pressure transducer which was connected to a continuous pen recorder. Thermocouples were located near the tip of each pitot tube.

### 3.5. Heat Flux

The heat flux into the surface of the specimen or the floor of the tunnel was measured with heat flux meters either attached directly to an ACB specimen with a high temperature cement or mechanically attached to a water-cooled plate. Silicon stop cock



grease was used to reduce the thermal contact impedance between the meter and the underlying surface. The term heat flux meter as used in this report refers to a flat plate device which consists of a sandwich of three ceramic wafers. The center one is wound with alternate lengths of dissimilar wires welded together to form a thermopile which measures the temperature difference across the wafer. The output voltage is proportional to the heat flux conducted through the meter. This is sometimes called a thermal ammeter. The exposed face of the meter was given a coat of velvet black paint whose absorptance is 0.97.

The second method of measuring the incident heat flux was approximate but permitted the measurement at many different locations simultaneously. Thermocouples were located on the front and rear surface every 0.1 m (4 in) along two 1.2 m (4 ft) lengths of asbestos millboard (AMB). After a steady difference in temperature between the rear and front surface was achieved, the heat flux conducted into the specimen at each location was calculated from this temperature difference and the known thermal conductivity of the material. The heat flux radiated from the exposed surface was calculated from its temperature assuming an emittance of unity. The incident heat flux at equilibrium was considered to be equal to the sum of the radiation from the exposed surface and the conduction losses through the specimen. An emittance of 0.96 at 38 °C (100 °F) has been reported for asbestos board [9].

#### 4. RESULTS AND DISCUSSION

##### 4.1. Noncombustible Specimens

###### 4.1.1. Temperature

In all of the standard tunnel tests the temperature is measured at a point 25 mm (1 in) below the specimen and a point 7.0 m (23 ft) from the burner and midway between the sides of the tunnel. The integral of the temperature rise over the ten-minute exposure period compared to that of an ACB specimen determines the heat contribution of the test specimen. This temperature history for an ACB specimen as recorded in UL 723 is reproduced in figure 3. During one of the instrumented tunnel tests on an ACB specimen the vertical temperature profiles were measured with an array of 10 thermocouples located at 0.92, 2.7, 4.3, 6.1 and 7.0 m (3, 9, 14, 20 and 23 ft). In figure 4 these profiles are compared at 10 minutes into the test. A peak temperature of about 800 °C (1500 °F) 25 mm (1 in) below the specimen is noted in the region of the burner flame. This is in the range of temperatures occurring 25 mm (1 in) from the ceiling of a room at the time of flashover. The temperature profile flattens as the air moves down the tunnel. Apparently the heat gained by the air in the lower part of the tunnel by mixing compensates for the heat losses to the floor so that the temperature near the floor doesn't change very much with distance.

Figure 5 shows the vertical variation of temperature along the wall for an ACB specimen at 4.3 m (14 ft) at four minutes. The data are badly scattered but they do indicate an average temperature of about 160 °C (340 °F) on the upper part of the wall.

This data was taken in order to estimate the expected radiation to the specimen. Note that a 160 °C (320 °F) black body surface will only radiate about  $0.21 \frac{\text{W}}{\text{cm}^2}$  ( $0.18 \frac{\text{Btu}}{\text{ft}^2 \cdot \text{s}}$ ).

The temperature of the lower exposed and upper unexposed surfaces of a 13-mm (1/2-in) thick AMB specimen is plotted as a function of distance after a 20-minute exposure in figure 6. The maximum exposed surface temperature of about 650 °C (1200 °F) occurs 0.61 m (2 ft) downstream from the burner. The calculation of the heat flux from these temperature distributions was described in subsection 3.5. The temperature distribution 25 mm (1 in) below an AMB specimen after 10 minutes is also shown in figure 6 in order to provide an estimate of the expected temperature gradient in the gas phase for heat transfer considerations. The gas temperature was nearly constant after 5 minutes. The lateral distribution of temperature across the exposed and unexposed surfaces of the AMB specimen and 25 mm (1 in) below it at 0.76 m (2.5 ft) is shown in figure 7 after a 20-minute exposure. The rear wall is the wall opposite to the one containing the viewing windows. These profiles covering one-half of the tunnel width show the degree of error incurred by assuming that the centerline temperature is the average over the total width. The reduction in the area under the curves due to heat losses at the wall was less than 5 percent. Data was not taken on the window side to check the effect of symmetry.

#### 4.1.2. Oxygen Concentration

The decrease in oxygen concentration of the air leaving the tunnel provides an approximate measure of the heat released by the specimen. This is based on the assumption that for a given volume of oxygen consumed there will be a fixed amount of heat released regardless of the type of fuel. While this amount does vary, the variation is relatively small over a wide range of materials which are tested in the tunnel as seen in table 2. The values tabulated for the polymeric materials are calculated from the table appearing in an article by Throne and Griskey [10]. The tabulated heats of combustion are based upon complete combustion with all the carbon and hydrogen present in the reactants appearing in water and carbon dioxide in the products. The heat of combustion of cellulose is taken from Johnson [11] while the heats of combustion for hydrogen, carbon, and methane, included for reference purposes are taken from the Handbook of Chemistry and Physics [12]. The differences between the net and gross heats of combustion for the various materials were determined by multiplying the mass of water formed by its heat of vaporization which was taken to be  $2.49 \frac{\text{kJ}}{\text{g}}$  ( $1072 \frac{\text{Btu}}{\text{lb}}$ ). In calculations involving the air temperature rise in the tunnel or in a room fire we are concerned with the net heat of combustion since the water formed during the combustion process remains in the gaseous state in the region of interest. It is noted in the table that methane produces  $16.4 \frac{\text{MJ}}{\text{m}^3}$  ( $441 \frac{\text{Btu}}{\text{ft}^3}$ ) of oxygen consumed and that this value represents all of the entries in the table to within  $\pm 15\%$  (Hydrogen excluded). If the chemical composition and heat of combustion of the material are known then its heat produced per unit volume of oxygen consumed can be calculated. However, the real value may deviate some from the calculated value if combustion is not complete.

Table 2. Heat Produced per Volume of Oxygen Consumed for Some Common Polymeric Materials

Materials	Heat of Combustion		Oxygen Requirement at 25 °C		Heat Produced per Volume of Oxygen Consumed at 25 °C	
	Gross (MJ/kg) (Btu/lb)	Net (MJ/kg) (Btu/lb)	(m <sup>3</sup> /kg)	(ft <sup>3</sup> /lb)	Gross (MJ/m <sup>3</sup> ) (Btu/ft <sup>3</sup> )	Net (MJ/m <sup>3</sup> ) (Btu/ft <sup>3</sup> )
Polyethylene	46.6 20,050	43.4 18,670	2.63	41.9	17.8 479	16.5 446
Polypropylene	46.5 20,030	43.3 18,650	2.63	41.9	17.7 478	16.5 445
Polystyrene	41.5 17,850	39.7 17,110	2.36	37.6	17.6 474	16.9 455
Polyvinyl Chloride	17.9 7,720	16.9 7,260	1.08	17.2	16.6 449	15.7 422
Polyethyl Methacrylate	26.7 11,470	25.2 10,830	1.47	23.5	18.1 488	17.1 461
Phenol-formaldehyde (1:1)	27.9 12,000	26.7 11,480	1.86	29.7	15.0 404	14.3 386
Urea-formaldehyde (1:2)	17.8 7,680	16.8 7,220	1.02	16.3	17.5 471	16.4 443
Melamine-formaldehyde (1:3)	19.3 8,310	18.4 7,950	1.14	18.1	17.0 459	16.3 439
Polyurethane, ester based	23.7 10,180	22.4 9,650	1.32	21.1	17.9 482	17.0 457
Unsaturated polyesters	29.8 12,810	28.4 12,220	1.58	25.2	18.8 508	18.0 484
Butadiene/styrene (25:5%) Copolymer (GRS rubber)	44.2 19,010	41.9 18,020	2.46	39.3	18.0 484	17.0 459
Butadiene/acrylonitrile (37%) Copolymer	39.9 17,180		2.21	35.3	18.1 487	
Natural rubber	45.3 19,490		2.53	40.3	18.0 484	
Cellulose	16.6 7,160	15.2 6,560	0.91	14.5	18.3 494	16.8 452
Carbon	32.8 14,100	32.8 14,100	2.05	32.7	16.0 431	16.0 431
Hydrogen	143.0 61,550	120.6 51,900	6.14	98.0	23.3 628	19.6 529
Methane	55.8 24,000	50.2 21,590	3.07	49.0	18.2 490	16.4 441

Actually this deviation may be small because the reduction in heat produced is accompanied by a roughly equivalent drop in oxygen consumed. The heats of pyrolysis, dehydration, and evaporation for the material are included in its measured gross heat of combustion in the oxygen bomb calorimeter. The release of volatiles from the specimen surface and chemical reactions in the gas phase lead to volume changes in the flow which can also affect the oxygen concentration. This source of error, not considered to be large, is not considered here. In spite of these effects it is expected that the measured oxygen depletion would yield approximate values of the heat released in the tunnel which are better than those obtained by calorimetric methods because of the significantly high rate of heat losses in the tunnel.

The oxygen depletion is defined by

$$\delta = \frac{Y_o - Y}{Y_o} \times 100 \text{ percent} \quad (1)$$

where  $Y$  is the oxygen concentration during the test and  $Y_o$  is the concentration prior to the test. The determination of the oxygen consumed depends on knowing the mass flow rate of the air as well as the oxygen depletion and it is assumed that the depletion is constant over the cross section of the duct. The mass flow is nominally 0.207 kg/s (27.5 lbs/min) but drops by as much as 20 percent during the test for some materials in some tunnels [7]. The rate of air inflow should be monitored during the test. In fact it is hoped in the upgrading of the tunnel by the tunnel operators that the air velocity into the tunnel would be controlled rather than the pressure drop across the tunnel and the duct, thereby providing better uniformity between tunnels and a constant inflow air velocity in all of them. The gases are well mixed by the time they reach the sampling point near the pressure tap in the duct. This was verified by traversing the duct in the vertical direction with the sampling probe. Figure 8 shows the oxygen concentration measured at the centerline of the duct for an ACB specimen. The sampling point is at the location of the pressure tap approximately 22 ft downstream from the end of the tunnel. The 13-percent depletion is due to the consumption of oxygen by the burner flame. However, this value is reached relatively slowly due to lags in the measurement system. This poor time response is the source of some error in the peak oxygen depletion measured during short duration burns. However, the small cost and relative ruggedness of the cells justified their use in the preliminary investigation. In most of the cases this response was enough. The high temperature oxygen cell used later in the project provided a faster responding system.

The variation of oxygen concentration with distance on the floor of the tunnel due to mixing is shown in figure 9. The concentration is reduced about 0.6 percent at 3.1 m (10 ft) and about 1.8 percent at 5.5 m (18 ft). In a room fire the oxygen concentration is near normal in the free stream but drops as the flaming region is approached. In the tunnel the airflow near the floor should represent the free stream conditions of airflow temperature, and oxygen concentration insofar as possible. The additional drop in oxygen concentration caused by combustible specimens will be presented in subsection 4.4.4. Figure 10 shows the vertical oxygen concentration profile at 2.7 m (9 ft) in



the tunnel with an ACB specimen. The oxygen depletion profiles obtained at five minutes with the high temperature oxygen cell at 0.92, 2.7, 4.3, and 7.0 m (3, 9, 14, and 23 ft) midway between the walls of the tunnel are shown in figure 11. The oxygen depletion measured in the duct was 12.8 percent while the average depletion at 0.92 m (3 ft) was 18 percent. This difference can qualitatively be accounted for by the reduced mass flow rate of the heated air in the upper part of the tunnel.

#### 4.1.3. Air Velocity

A knowledge of the air velocity profiles as well as the temperature profiles in the tunnel are necessary for computing the quantity of heat being carried along by the air and for estimating the heat transfer to the ceiling, walls, and floor. The rate of heat transfer to the specimen forming the ceiling controls its fuel production rate which in turn determines the flame distance and hence its FSC. Figure 12 shows the ambient velocity distribution measured across the tunnel at midheight and 7.2 m (23.75 ft) from the burner using a hot film anemometer. This profile is taken during the normal calibration runs of the tunnel to establish the average air velocity. In order to obtain the velocity profiles at elevated temperature it was necessary to use pitot tubes. Two factors limit the accuracy of these measurements. First, the velocities are below the optimum operating range of the pressure sensor producing pressure differentials in many cases of less than 2.5 Pa (0.01 in of water). Second, the introduction of the air through a slit near the floor of the tunnel, the location of the seven bricks purposely used to increase turbulence, and even the thermocouple tree and the ten pitot tubes along with their copper tubing running the length of the tunnel produced eddies which could cause a misalignment of the direction of airflow and the axis of the pitot tube. Nevertheless these distributions were determined and they are of the proper magnitude to roughly account for the total mass flow rate of the air. The vertical velocity profile of the ambient air measured with pitot tubes at 2.7 m (9 ft) from the burner is shown in figure 13. The relatively flat profiles of both figures 12 and 13 are characteristic of turbulent flow. The Reynolds number is approximately 30,000.

When the burner was turned on the profile shown in figure 14 was obtained. If there were no vertical transfer of momentum and the mass inflow of air were to remain constant, the velocity would be proportional to the absolute temperature of the air. The dashed curve was obtained by dividing the velocity by the ratio of the absolute temperature and the ambient absolute temperature,  $T/T_0$ . The departure of this dashed curve from the distribution in figure 13 demonstrates the presence of such momentum transfer. The slope of the velocity profile should decrease with distance down the tunnel due to momentum transfer. Figure 15 shows the velocity profiles at 4.3 and 6.1 m (14 and 20 ft) with the burner on and at 6.1 m (20 ft) with the burner off.

In order to look for changes in the mass inflow rate the thermoanemometer was positioned just in front of the entrance slit to the tunnel where the relative change in inflow velocity could be recorded. A record of the output of this probe versus time is shown in figure 16. Initially there is a drop in the inflow velocity as the burner



is turned on. This transient lasts long enough for the expanded hot air to follow the slower moving ambient air through the tunnel and out the duct. The original inflow velocity was restored in about six seconds. While the average inflow rate does not seem to be changed, the instantaneous inflow shares some of the turbulence developed in the tunnel.

The volumetric air inflow rate,  $V_a$  can also be calculated from the oxygen depletion in the stack with the methane burner serving as the only source of fuel.

$$V_a = \frac{SV_g}{0.01 \beta Y_o} \quad (2)$$

where S is the number of volumes of oxygen needed for complete combustion of one volume of fuel, and  $V_g$  is the volumetric delivery rate of the gas.  $S=2$  for methane and  $V_g$  is  $2.3 \text{ dm}^3/\text{s}$  ( $4.9 \text{ cfm}$ ) for the tunnel. The oxygen concentration in normal air,  $Y_o$ , is 0.208. Using the 13 percent oxygen depletion measured in the exhaust duct with the ACB specimen (figure 8)  $V_a$  is estimated to be  $0.17 \text{ m}^3/\text{s}$  ( $362 \text{ cfm}$ ). The cross sectional area of the tunnel is  $0.14 \text{ m}^2$  ( $1.46 \text{ ft}^2$ ), so the average linear velocity at ambient temperature is  $1.3 \text{ m/s}$  ( $248 \text{ ft/min}$ ). This average velocity is close to that estimated from the velocity profile obtained with the pitot tubes in figure 13,  $1.3 \text{ m/s}$  ( $250 \text{ ft/min}$ ), and the thermoanemometer in figure 12,  $1.2 \text{ m/s}$  ( $245 \text{ ft/min}$ ). The velocity averaged over both vertical and horizontal directions could be somewhat lower. The nominal velocity is  $1.2 \text{ m/s}$  ( $240 \text{ ft/min}$ ) at  $41^\circ\text{C}$  ( $105^\circ\text{F}$ ) which would be reduced to  $1.1 \text{ m/s}$  ( $225 \text{ ft/min}$ ) at ambient temperature.

The 10 percent difference could be due to errors in velocity and oxygen concentration measurements, incomplete combustion, air leakage into the tunnel, or actual variations in mass inflow of air through the tunnel.

#### 4.1.4. Pressure Drop in the Tunnel

In order to estimate the effective friction factor inside of the tunnel and the flow impedance of the entrance slit, the pressures were monitored at several points. These parameters are important in estimating the heat transfer and the variation in velocity with the air temperature and the pressure differential across the tunnel. According to the UL flammability studies [6] the variation in velocity appears to have a small effect on flame spread distances in the tunnel but a large one on the smoke concentration in the duct. The negative pressures as determined from the side port of a pitot tube aligned with the axis of the tunnel and located on the floor with the burner off are shown as a function of distance from the burner in figure 17. These measurements were made at ambient temperatures. The variation in pressure is small compared with the scatter. Nonetheless a slope was estimated to be  $0.20 \text{ Pa/m}$  ( $2.4 \times 10^{-4} \text{ in of water/ft}$ ) using a least squares fit. The friction factor,  $f$ , is calculated from the relationship [12]:

$$f = gD(\Delta P/L)/(2 \rho V^2) \quad (3)$$

where  $g$  is the newton constant ( $1 \text{ m kg/Ns}^2$ ;  $32.2 \text{ ft lb/lbfS}^2$ ),  $\Delta P$  is the pressure difference ( $\text{lb/ft}^2$ ) over the length  $L$ (feet),  $\rho$  is the air density ( $1.22 \text{ kg/m}^3$ ;  $0.0763 \text{ lb/ft}^3$ ),  $V$  is the velocity ( $1.22 \text{ m/s}$ ;  $4 \text{ ft/sec}$ ), and  $D$  is the hydraulic diameter ( $0.37 \text{ m}$ ;  $1.2 \text{ ft}$ ). The hydraulic diameter is equal to 4 times the cross sectional area divided by the perimeter. A pressure of  $249 \text{ Pa}$  ( $1 \text{ in of water}$ ) is equal to  $249 \text{ N/m}^2$  ( $5.2 \text{ lbf/ft}^2$ ). The calculated value of  $f$  from equation (3) is  $0.020$ . The accuracy of this calculation suffers from the scatter of the data, but the result leads to a prediction of the heat transfer which is roughly in agreement with the other methods which will be discussed.

The Reynold's number,  $Re = \frac{VD}{\nu}$ , is  $30,000$  based on a velocity,  $V$ , of  $1.2 \text{ m/s}$  ( $4 \text{ ft/sec}$ ), a kinematic viscosity,  $\nu$ , of  $0.15 \text{ cm}^2/\text{s}$  ( $1.6 \times 10^{-4} \text{ ft}^2/\text{sec}$ , and a hydraulic diameter of  $0.37 \text{ m}$  ( $1.2 \text{ ft}$ ). For smooth tubes,

$$f \approx (0.046)/(Re)^{0.2} \quad (4)$$

so the smallest value  $f$  could assume is  $0.006$ . A typical value for concrete surfaces is  $0.01$  [13]. The value derived from figure 17 is twice as high but there are large scale irregularities in the tunnel including the added turbulence bricks. It is clear from the figure that a large fraction of the pressure drop is across the entrance region of the tunnel. This large flow impedance which is independent of temperature has a stabilizing effect on the mass inflow rate of air in the tunnel particularly since the impedance of the tunnel itself increases with air temperature.

The measurement of the pressure drop in the tunnel can be used to estimate the effect of the distance and location of the pressure tap on the change in the mass inflow rate of the air during a regular tunnel test. Figure 18 is a simplified sketch of a vertical cross section of the tunnel, riser, and exhaust duct showing the specific pressure points needed for this development. The following relationship between the pressures must hold:

$$(P_0 - P_1) + (P_1 - P_2) + (P_2 - P_3) + (P_3 - P_4) + (P_4 - P_5) = P_0 - P_5 = P_0 g z$$

or

$$\Delta P_{\text{slit}} + \Delta P_{\text{tunnel}} + \Delta P_{\text{riser}} + \Delta P_{\text{duct}} + \Delta P_{\text{tap}} = P_0 g z \quad (5)$$

The drop in pressure across the slit is proportional to the kinetic energy of the flow so that  $\Delta P_{\text{slit}} = k \rho V_0^2$ . The pressure drop across the tunnel and the exhaust duct are given by equation 3. The pressure drop in the riser is given by  $\rho g z$  and  $\Delta P_{\text{tap}}$  is controlled at a fixed negative value throughout the test. Then equation 5 can be written

$$k\rho_o V_o^2 + 2\rho_T V_T^2 \frac{f_T}{g} \frac{L_T}{D_T} + 2\rho_D V_D^2 f_D \frac{L_D}{D_D} = -\Delta P_{tap} + (P_o - P) gz$$

$$\text{Since } G = \rho_o V_o = \rho_T V_T = \rho_D V_D \text{ and } \rho = \frac{T_o}{T} \rho_o,$$

$$\frac{G^2}{\rho_o} = \frac{-\Delta P_{Tap} + (1 - T_o/T_R) P_o gz}{k + \frac{2}{g} (f_T \frac{L_T}{D_T} \frac{T_T}{T_o} + f_D \frac{L_D}{D_D} \frac{T_D}{T_o})}$$

$$G = \sqrt{\rho_o} \left[ \frac{-\Delta P_{tap} + (1 - T_o/T_R) \rho_o gz}{K + \frac{2}{g} (f_T \frac{L_T}{D_T} \frac{T_T}{T_o} + f_D \frac{L_D}{D_D} \frac{T_D}{T_o})} \right]^{1/2} \quad (6)$$

where the subscripts T, D, and R refer to the average values of these parameters in the tunnel, exhaust duct, and riser respectively. Taking  $f_T = f_D = 0.02$  and measuring G at ambient temperature a value of 15.5 was calculated for K.

Since all tunnels do not share the same differences in height between the tunnel and the pressure tap, z, there will be differences in the effective pressure across the tunnel when the temperature of the air in the duct is rising during a test. This means that there may be significant mass inflow velocity differences between tunnels during their operation which may cause some changes in flame spread and larger changes in smoke transmission. For uniformity between tunnels either (1) the pressure taps should be at the same elevation and distance from the end of the tunnel, (2) the airflow should be controlled directly from the measured velocity at the entrance slit or (3) the pressure tap should be located upstream of the burner where the air temperature is not changing during the test. In updating existing tunnels the latter alternatives would be more feasible.

#### 4.1.5. Heat Flux

The response of a material to a fire environment, as measured by its ignitability, heat release rate, and rate of flame spread, depends on its incident heat flux. The comparison between the heat fluxes in a room fire and those in the tunnel are of the utmost importance.

It is difficult to measure the heat flux without altering the quantity being measured. The incident heat flux is due to both radiation and convection. The latter depends on the difference between the gas and surface temperature. Since the surface temperature of a burning specimen will be in excess of 315 °C (600 °F) the heat absorbed at the surface of the specimen will be less than that for a water-cooled Gardon heat flux gage or water-cooled heat flux meter flush with the surface. Nevertheless, measurements with a water-cooled heat flux meter were collected so that a direct comparison could be made with the water-cooled Gardon total heat flux gage used in the full-scale corner and room tests. Measurements made on the surface of an ACB specimen

0.61 m (2.0 ft) from the burner, with a water-cooled heat flux meter yielded a maximum flux of  $6.3 \text{ W/cm}^2$  ( $5.5 \text{ Btu/ft}^2 \cdot \text{sec}$ ) as seen in figure 19. This is in the region of flame impingement from the burner. The range of incident heat fluxes measured 1.2 m (4 ft) above the floor in the UL corner tests with the 9.1-kg (20-lb) crib [6] ran between  $6.0$  and  $8.4 \text{ W/cm}^2$  ( $5.3$  and  $7.4 \text{ Btu/ft}^2 \cdot \text{sec}$ ) by the time the flames had covered the ceiling. The 1.2-m (4-ft) elevation was chosen so that the flux measurement would be well within the area of impingement of the crib flame.

In another measurement made at 0.76 m (2.5 ft) with the heat flux meter attached directly to the ACB without water cooling, the flux conducted into the specimen was observed to be  $4.0 \text{ W/cm}^2$  ( $3.5 \text{ Btu/ft}^2 \cdot \text{sec}$ ). When the ACB surface rose in temperature, there was a reduction in the heat transferred to the surface and furthermore, part of the incident heat flux was radiated away so that the actual incident heat flux was greater than  $4.0 \text{ W/cm}^2$  ( $3.5 \text{ Btu/ft}^2 \cdot \text{sec}$ ) but less than  $6.3 \text{ W/cm}^2$  ( $5.5 \text{ Btu/ft}^2 \cdot \text{sec}$ ).

As was explained in subsection 3.5 the heat flux distribution along a 13-mm (1/2-in) thick AMB specimen over the entire length of the tunnel was estimated by attaching 0.25 mm (10 mil) thermocouples every 0.1 m (4 in) along the length of two 1.2-m (4-ft) sections on both the exposed and unexposed surfaces. Twenty-minute runs were made with the boards between 0 and 2.4 m (0 and 8 ft), then 2.4 and 4.9 m (8 and 16 ft), and finally between 4.9 and 7.3 m (16 and 24 ft). This time was sufficient to establish nearly steady flow through the specimen. The temperature data is presented in figure 6. The thermal conductivity of the AMB was measured to be  $0.135 \text{ W/m} \cdot \text{K}$  ( $2.17 \times 10^{-5} \text{ Btu/sec} \cdot \text{ft} \cdot ^\circ\text{F}$ ). The incident heat flux,  $H$ , which was partly conducted through the specimen with the remainder radiated from its surface, was calculated from the formula

$$H = \frac{K}{x} (T_s - T_r) + \epsilon \sigma T_s^4 \quad (7)$$

where  $K$  is the thermal conductivity,  $x$  is the thickness,  $T_s$  is the front surface temperature,  $T_r$  is the rear surface temperature,  $\epsilon$  is the emittance which is assumed to be unity, and  $\sigma$  is the Stefan Boltzmann constant.

The results of this calculation are plotted in figure 20. The magnitude of the heat flux will depend on the material. The distribution for AMB is taken as a typical one. The amplitude will actually increase somewhat for materials of higher thermal conductivity. For the AMB it is seen to be a peaked distribution which drops to essentially half of its maximum value at the end of the burner flame.

This is consistent with the general principle of calling the flame distance the furthest point at which flame is present half of the time. Note that the flux at 0.76 m (2.5 ft) was calculated to be  $3.75 \text{ W/cm}^2$  ( $3.3 \text{ Btu/ft}^2 \cdot \text{s}$ ) for AMB whereas for ACB which had a thermal conductivity of  $0.36 \text{ W/m} \cdot \text{K}$  ( $5.8 \text{ Btu/sec} \cdot \text{ft} \cdot ^\circ\text{F}$ ) and a thickness of 6.4 mm (1/4-in) it was measured to be between  $4.0$  and  $6.3 \text{ W/cm}^2$  ( $3.5$  and  $5.5 \text{ Btu/ft}^2 \cdot \text{sec}$ ).

In order to estimate the convective component of the heat flux to the surface, the momentum heat transfer analogy [13] was used. The surface heat transfer coefficient,  $h$ , is given according to this analogy by

$$h = \frac{Ef}{2} \rho CV \quad (8)$$

where  $E$  is the ratio of the eddy diffusivities for heat and momentum (approximately unity for air),  $f$  is the friction factor, measured to be 0.020,  $\rho$  is the density,  $C$  is the heat capacity and  $V$  is the air velocity. The product  $\rho V$  is approximately constant and equal to its ambient value (1.5 kg/m<sup>2</sup>·s (0.31 lb/ft<sup>2</sup>·sec)). The average value of  $C$  between 20 °C (70 °F) and 800 °C (1500 °F) is 1.1 kJ/kg·K (0.26 Btu/lb·°F). Hence  $h = 16.5 \text{ W/m}^2\cdot\text{K}$  (0.00081 Btu/ft<sup>2</sup>·sec·°F). The convective heat flux,  $H_c$ , is given by

$$H_c = h\Delta T \quad (9)$$

From figure 6 the air temperature 25 mm (1 in) below the AMB at 7.0 m (23 ft) is 338 °C (640 °F). The temperature of the surface is 204 °C (400 °F). Putting this temperature difference in equation (7) yields a convective heat flux of 0.22 W/cm<sup>2</sup> (0.19 Btu/ft<sup>2</sup>·sec). The estimated total incident heat flux from figure 19 at 7.0 m (23 ft) was 0.38 W/cm<sup>2</sup>. While both of these numbers contain considerable approximation, the convective component is of the correct order of magnitude to account for most of the total heat flux near the end of the tunnel. Radiation from the wall and floor will also provide some contribution. For example, if the average temperature of the walls and floor were half that of the AMB surface the radiation contribution would be 0.14 W/cm<sup>2</sup> (0.12 Btu/ft<sup>2</sup>·sec).

A plot of the convective component of the heat flux distribution between 1.2 m (4 ft) and 6.1 m (20 ft) based on the momentum-heat transfer analogy using the air and exposed surface temperatures in figure 6 is given in figure 21. Comparison with the total heat flux distribution indicates that beyond 2.4 m (8 ft) in the tunnel the heat transfer might be accounted for by using the above analogy for convection and by taking wall radiation into account. However, flame radiation and other heat transfer mechanisms must be considered in order to take the large difference between these curves into account in the flame region. Figure 6 indicates a temperature difference of 288 °C (550 °F) between the AMB surface and the temperature 25 mm (1 in) below it at 0.76 m (2.5 ft). Equation (9) yields a convective heat flux of only 0.48 W/cm<sup>2</sup> (0.42 Btu/ft<sup>2</sup>·sec) whereas the estimated total heat flux was 3.75 W/cm<sup>2</sup> (3.3 Btu/ft<sup>2</sup>·sec).

Yet another way to estimate the heat flux to the surface is to determine the rate of loss of the enthalpy of the air as it passes down the tunnel.

$$Q_L = \rho V_a C \Delta T \quad (10)$$



This would result in a total rate of heat transfer of 3.5 kW (3.3 Btu/sec). If the flow is assumed to be two-dimensional, then the losses would be only through the specimen and the floor of the tunnel. The area of the floor and the specimen between 6.1 and 7.0 m (20 and 23 ft) is  $0.84 \text{ m}^2$  ( $9 \text{ ft}^2$ ). The average rate of heat transfer would be  $0.41 \text{ W/cm}^2$  ( $0.36 \text{ Btu/ft}^2\cdot\text{sec}$ ). Between 2.7 and 4.3 m (9 and 14 ft) the average temperature difference was  $45^\circ\text{C}$  ( $80^\circ\text{F}$ ) which yields an average heat flux to the surface of  $0.66 \text{ W/cm}^2$  ( $0.58 \text{ Btu/ft}^2\cdot\text{sec}$ ). These estimated heat fluxes are plotted in figure 21 for comparison with the other methods.

The heat flux measured on the ceiling of the tunnel by a water-cooled heat flux meter at 4.3 m (14 ft) was  $0.64 \text{ W/cm}^2$  ( $0.56 \text{ Btu/ft}^2\cdot\text{sec}$ ). Because of the lower surface temperature this value would be expected to be somewhat higher than that to the specimen surface. The heat flux measured on the floor of the tunnel at 4.3 m (14 ft) with a water-cooled heat flux meter was  $0.34 \text{ W/cm}^2$  ( $0.30 \text{ Btu/ft}^2\cdot\text{sec}$ ) or approximately one-half of that on the ceiling. The latter measurement was made with the AMB specimen.

The purpose of trying to determine the heat flux by as many methods as possible was to put its distribution on firmer ground in order to provide a basis for the flame spread model. The heat fluxes obtained by the various methods are all included in figure 21.

#### 4.2. Experiments with the Auxiliary Burner

##### 4.2.1. General

In the previous sections, the temperatures, velocities, oxygen depletion, heat fluxes, and pressures were reported for inert specimens. Before proceeding with combustible specimens a set of experiments was conducted with an auxiliary burner which delivered known flow rates of methane to simulate the gaseous decomposition products, "fuel," that would be released by a combustible specimen. The purpose of these experiments was to examine:

- (1) the relationship between the flame distance and the rate of fuel production,
- (2) the validity of using the oxygen depletion in the duct as a measure of the rate of fuel production of the combustible specimens, and
- (3) the effect of the rate of fuel production and flame length on the oxygen, temperature, velocity, and heat flux distributions in the tunnel.

##### 4.2.2. Flame Distance

The reported flame distance versus time is shown in figure 22. The rate of flow delivered by the auxiliary burner is marked on each plateau of this plot. The regular burner with  $2.3 \text{ dm}^3/\text{s}$  ( $4.9 \text{ cfm}$ ) is started at time zero and is left on during the run. Note that as the flow to the auxiliary burner is increased, the maximum flame distance

takes some time to establish. In particular at a flow of  $2.4 \text{ dm}^3/\text{s}$  ( $5.0 \text{ cfm}$ ) through the auxiliary burner it takes 1.5 minutes for the flame to reach its maximum distance even with a steady flow of methane. This effect was not explored further, but was merely noted because of the bearing that it might have in the development of a flame spread model for the tunnel. No attempt was made to examine the buildup time of the regular burner flame. The maximum flame distances are plotted against the total flow rate of methane in figure 23. The total flow rate includes the  $2.3 \text{ dm}^3/\text{s}$  ( $4.9 \text{ cfm}$ ) flow to the regular burner plus the flow rates to the auxiliary burner. The flame distance is the distance from the burner to the downstream end of the flame.

Beyond the burner flame the distance increases linearly with the flow rate with a slope of  $19 \text{ s/dm}^2$  ( $3.0 \text{ ft/cfm}$ ). It is seen, however, that the  $2.3 \text{ dm}^3/\text{s}$  ( $4.9 \text{ cfm}$ ) contributed by the regular burner was not nearly as effective in contributing to the flame length in the tunnel. This is probably because the burner fuel is delivered from ports  $0.10 \text{ m}$  ( $4 \text{ in}$ ) above the floor and much of the fuel is burned before it reaches the specimen  $0.3 \text{ m}$  ( $1 \text{ ft}$ ) or more downstream of the burner. On the other hand, the fuel from the auxiliary burner was delivered at the specimen surface in a region already supplied by the regular burner so that its burning would take place in the proximity of the surface and some distance downstream. The fuel delivered or generated at the specimen surface has access to oxygen from one side only and is in the proximity of a heat sink. Both of their effects tend to reduce the burning rate and thus extend the flame area. The heat production rate of the flame from the auxiliary burner is  $3.9 \text{ W/cm}^2$  ( $3.4 \text{ Btu/ft}^2\cdot\text{sec}$ ) assuming a net heat of combustion for methane of  $34 \text{ MJ/m}^3$  ( $912 \text{ Btu/ft}^3$ ), a flame width of  $0.46 \text{ m}$  ( $1.5 \text{ ft}$ ), and the above slope of  $19 \text{ s/dm}^2$  ( $3.0 \text{ ft/cfm}$ ).

#### 4.2.3. Oxygen Depletion

Figure 24 shows that the relationship between the oxygen depletion in the duct and the total flow rate of methane is essentially linear with a slope of  $6.8\%/ \text{dm}^3$  ( $3.2\%/ \text{cfm}$ ). Since the auxiliary burner introduced some impedance there was a decrease in airflow of about 20 percent as indicated by an increase in oxygen depletion with the auxiliary burner in place but not turned on. Without the auxiliary burner installed, the regular burner flow of  $2.3 \text{ dm}^3/\text{s}$  ( $4.9 \text{ cfm}$ ) produced a depletion of 13 percent or  $5.7\%/ \text{dm}^3$  ( $2.7\%/ \text{cfm}$ ). Taking a net heat of combustion of  $34 \text{ MJ/m}^3$  ( $912 \text{ Btu/ft}^3$ ) for methane and assuming that a given volume of oxygen consumed produces the same amount of heat regardless of the material, the total rate of heat generation including that from the regular burner is given approximately by

$$Q = 6.0 \beta \text{ kW} = 340 \beta \text{ Btu/min} \quad (11)$$

where  $\beta$  is the oxygen depletion in percent.

Equation (11) provides a means of determining the heat generated by a specimen during the test. This is superior to the use of the regular fuel contribution thermocouple at  $7.0 \text{ m}$  ( $23 \text{ ft}$ ) because the heat losses upstream of the thermocouple limit the temperature rise particularly when large concentrations of smoke are present in the tunnel.

The oxygen concentration on the floor of the tunnel at 2.7 m (9 ft) as a function of fuel flow is given in figure 25. At the highest flow rate the flame exceeds the length of the tunnel, but the oxygen concentration on the floor has been reduced by only about two percent of its initial value. This low value of oxygen depletion is important in establishing the similarity between burning in the tunnel and in the room. A high oxygen concentration at the floor level of the tunnel should be equivalent to a high oxygen concentration in the free stream some distance away from the burning surface in the room.

#### 4.2.4. Temperature

The temperatures recorded at the end of four minutes by the standard fuel contribution thermocouple located at 7.0 m (23 ft) are plotted as a function of total methane flow in figure 26. The tunnel is preheated and cooled to 41 °C (105 °F) before starting each test, hence the 41 °C (105 °F) intercept of the curve which appears to be fairly linear with a slope of 88 K·s/dm<sup>3</sup> (75 °F/cfm) of methane. If it is assumed that the temperature 25 mm (1 in) below the surface represents the average value, through the cross section of the tunnel this slope would correspond to a 6.4 kJ/s (363 Btu/min) increase in enthalpy flow for each 0.47 dm<sup>3</sup>/s (1 cfm) of methane. Since the methane has a net heat of combustion of 34 J/cm<sup>3</sup> (912 Btu/ft<sup>3</sup>) and the average temperature is actually lower than that recorded by the thermocouple, over 60% of the heat is conducted through the ACB specimen or lost through the walls of the tunnel. This absorption of heat within the tunnel would tend to be less for a lower thermal conductivity specimen but more for a smoke producing specimen because of thermal radiation from the smoke particles to the interior surfaces of the tunnel.

Figure 27 shows the increase in temperature at 2.7 m (9 ft) for an additional flow of 2.4 dm<sup>3</sup>/s (5 cfm) of methane. Figure 28 shows the temperature profiles for a series of flow rates at 4.9 m (16 ft). The similarity of the profiles is noteworthy and it is of significance to the model development that increasing the total flow from 4.7 to 5.4 dm<sup>3</sup>/s (9.9 to 11.5 cfm) causes essentially the same increase in temperature as the other steps even though a flow of 4.7 dm<sup>3</sup>/s (9.9 cfm) extended the burner flame 1.8 m (6 ft) past the 4.9 m (16 ft) location where the measurement was made. In figure 29 the vertical temperature profile is shown along the wall at 4.3 m (14 ft) for an auxiliary gas flow of 2.4 dm<sup>3</sup>/s (5 cfm). The temperature of the upper part of the wall is of the order of 315 °C (600 °F) which would give rise to a radiation level of about 0.7 W/cm<sup>2</sup> (0.6 Btu/ft<sup>2</sup>·sec). The distribution for the burner alone is included for comparison.

The temperature distribution on the exposed and unexposed surfaces along the length of the tunnel for an AMB specimen fully covered with the flame from an auxiliary burner with 2.8 dm<sup>3</sup>/s (6 cfm) of methane is seen in figure 30. The purpose of these measurements was to deduce the incident heat flux distribution along a specimen fully covered with flame.

#### 4.2.5. Velocity

The velocity profiles at 2.7 m (9 ft) are compared with the burner off, burner on, and burner on with 2.4 dm<sup>3</sup>/s (5 cfm) of methane delivered by the auxiliary burner in figure 31.

#### 4.2.6. Heat Flux

The heat flux distribution along an AMB surface covered with flame was deduced by the same methods as that used for the burner flame alone in section 4.1.5. It can be seen in figure 32 that these fluxes are considerably higher than for the burner flame alone. In fact the flux level at the end of the tunnel has only fallen to 2.7 W/cm<sup>2</sup> (2.4 Btu/ft<sup>2</sup>-sec). This is after a constant 20-minute exposure to the flame from the auxiliary burner and will contain some radiation from the walls and floor which builds up with time.

#### 4.2.7. Smoke

No attempt was made to measure the smoke density inside the tunnel but it is measured in the duct during the regular tunnel runs. It has also been recorded on the various instrumented tunnel tests. Because smoke affects the heat transfer in the tunnel it is an important part of the environment. The introduction of methane into the auxiliary burner has caused a small but measurable amount of smoke production. Methane is normally not a smoky flame but there are two conditions existing that could lead to smoke production. One is a reduced oxygen atmosphere and the other is flame quenching against the cold ceiling. In the case of combustible specimens both conditions are operating. For 3.1 dm<sup>3</sup>/s (6.6 cfm) of methane delivered to the auxiliary burner and 2.3 dm<sup>3</sup>/s (4.9 cfm) to the regular burner, the optical density produced in the duct was 0.14 per meter. The optical density is essentially zero with the regular burner alone.

### 4.3. Experiments with 0.92-Meter (3-ft) Combustible Specimens

#### 4.3.1. General

The next step in the project was to introduce combustible specimens but to confine them to the region of the burner flame so that uniform exposure conditions could be achieved as nearly as possible. Their location between 0.31 and 1.2 m (1 and 4 ft) beyond the burner ruled out any consideration of flame spread across the surface since the complete specimen would be involved almost at once. Although the peak heat flux to the surface does not change appreciably when the specimen begins to generate fuel, the rate of drop-off of this flux with distance (see fig. 20) would be decreased so that there will be some difference in the exposure for different materials. Nevertheless, in order to have adequate sensitivity a 0.92-m (3-ft) specimen length was chosen and the variation in the exposure was ignored for the present stage of the investigation.

The primary objective of this part of the project was to determine the fuel generation or heat release rates of the materials due only to their exposure to the burner flame. This rate was to be measured by the oxygen depletion in the duct according to equation (11). The second objective was to learn how the flame distance varied with the fuel production rate among the various combustible materials.

The predicted flame spread distance in the tunnel might then be expressed as a product of (1) the total rate of fuel production from the specimen and (2) the flame distance required to consume the fuel produced at a unit rate.

#### 4.3.2. Heat Release Rates

In order to determine the heat release rate per unit area equation (11) has to be divided by the area of the specimen so that

$$q = 1.44 (\beta - \beta_B) W/cm^2 = 1.27 (\beta - \beta_B) \text{ Btu/ft}^2 \cdot \text{sec} \quad (12)$$

where  $q$  is the heat release rate and  $\beta_B$  is the oxygen depletion produced by the burner alone. This value of  $\beta_B$  will be about 0.13 but does vary slightly so that it is measured in each series of tests with an ACB specimen. Table 3 lists the heat release rates for a number of materials used in the UL full-scale tests [6]. The heat release rates were obtained from equation (13) and are compared with those measured with the NBS heat release rate calorimeter at a radiant flux of  $3 W/cm^2$  ( $2.6 \text{ Btu/ft}^2 \cdot \text{sec}$ ). The materials tested in this way were broken up into four groups for discussion purposes. The distribution of the materials among the groups was based only on the data comparisons. Even though the incident heat flux varies across the face of the specimen in the tunnel, the agreement is quite good for the materials in group 1. In group 2 the values in the tunnel were much higher. In the calorimeter only materials A and B ignited and in these cases the flaming was probably limited to the gas phase above the specimen and hence contributed no heat feedback to the specimen. This speculation is based on observations of the burning of these materials in a  $3 W/cm^2$  ( $2.6 \text{ Btu/ft}^2 \cdot \text{sec}$ ) radiation field outside of the calorimeter. Unfortunately the exposed surface of the specimens is not visible in the NBS heat release rate calorimeter. In the tunnel all of the specimens are exposed to the burner flame. In group 3 the values produced in the tunnel were lower due to the limited time response of the oxygen measuring system which may not have been fast enough to follow the short duration peaks of these materials. The materials in group 4 are inordinately high smoke producers. This smoke tends to radiate the heat away rapidly. This may account for these lower measured values of heat release rate in the calorimeter. Some evidence for this radiation loss is seen in the temperature records for the 7.0 m (23 ft) thermocouple in the tunnel which indicate  $290^\circ\text{C}$  ( $555^\circ\text{F}$ ) after five minutes for an ACB specimen and only  $117^\circ\text{C}$  ( $350^\circ\text{F}$ ) for a 0.92-m (3-ft) type "O" specimen even though it produced a considerable amount of heat.



Table 3. Peak Heat Release Rates Deduced from the Oxygen Depletion in the Duct Compared with those from the NBS Heat Release Rate Calorimeter at 3 W/cm<sup>2</sup>

Material Designation	Thickness (mm)	Density (kg/m <sup>3</sup> )	Material Type	FSC	Tunnel (W/cm <sup>2</sup> )	Calorimeter (W/cm <sup>2</sup> )	Group
S	50	37	F.R. Polyisocyanurate	26	2.0	2.1	1
C	50	30	F.R. Polyurethane	28	2.3	2.3	1
J	13	290	Wood Fiberboard	54	3.6	4.0	1
Q	50	32	F.R. Polyurethane	28, 59	7.6	7.4	1
AE	20	620	Red Oak Flooring	100	9.1	9.4	1
U	13	759	Wood Particle Board	156	11	11	1
H	6	530	Prefinished Luan plywood	178	14	12	1
B	50	30	F.R. Polyurethane	28	3.1	2.3	2
A	50	30	F.R. Polyisocyanurate	22	4.1	0.8	2
I	13	300	F.R. Treated Wood Fiber-board	18	1.7	<0.3	2
T	13	800	F.R. Treated Wood Particle Board	18	2.0	<0.3	2
E	89	10	Fiber Glass	18	3.1	<0.3	2
R	50	37	Foil Faced F.R. Polyisocyanurate	26	4.1	<0.3	2
G	13	590	Treated Plywood	23	4.6	<0.3	2
W	16	1230	Gypsum Wallboard	13	0.5	<0.3	2
F	89	10	Paper Faced Fiber Glass	2540	9.7	13	3
D	50	29	F.R. Polyurethane	925	6.7	19	3
O	50	40	F.R. Polyurethane	1735	23	12	4
M	1.6	1340	Glass Fiber Reinforced Polyester	367	84	14	4

The agreement between the heat release rates based on oxygen depletion for the group 1 materials with their heat release rates measured directly in the calorimeter indicates the potential of the oxygen depletion in the duct as a measure of the fuel generation rate of a specimen in the tunnel.

#### 4.3.3. Flame Distance

The flame spread distances for 0.92 m (3 ft) specimens of a number of the materials used in the full-scale tests at UL [6] are given in table 4 along with the flame spread distances for full size specimens of the same materials. The similarity of the flame distances for the 0.92-m (3-ft) and the 7.9-m (24-ft) specimens of the low flame spread materials is quite striking. It indicates that most of the fuel which contributes to the extension of the flame for these materials is generated in the region exposed directly to the burner flame. Flame distance does not depend on the environmental conditions in the vicinity of the flame front for low FSC materials.

Table 4. Flame Distances in the Tunnel for  
3-Foot and 24-Foot Specimens

Material <sup>+</sup>	FSC	Called Flame Distance (ft)**	
		3-Foot	24-Foot
E	18	6.5	8
W	13	7	7
I	18	7.5	8
T	18	7.5	8
G	23	8.5	9
C	28	8.5	9.5, 10.5
A	22	9	8.5, 9.9
S	26	9	9.5
B	28	9	10
Q <sup>***</sup>	28, 59	9	9.5, 10, 16
R	26	10	9.5
J	54	10	15
AE	100	12	24
D	925	12	24
O	1735	12	24
H	178	13	24
U	156	14.5	24
F	2540	15	24

\* See description in table 3.

\*\* 1 foot = 0.305 meters

\*\*\* Material is highly variable in its flame distance in the tunnel.

The 0.92-m (3-ft) tests may be a useful way to compare the flame spread potential of materials, since even the high flame spread materials have flame extensions which terminate within the tunnel. Those materials which spread flame a distance of over 3.1 m (10 ft) in the 0.92-m (3-ft) test, spread flame over the end of the tunnel in the regular test and hence are normally rated for time of flame spread rather than distance. The 0.92-m (3-ft) specimen test would allow the comparison of all materials on the same scale. For flame spread distances of less than 3.1 m (10 ft) on the 0.92-m (3-ft) test, the distances were only 0.15 m (0.5 ft) less on the average than for the 7.9-m (24-ft) test. Specimen Q is a special case. Because of the variability of this material as evidenced by the different flame spread distances in the regular tunnel tests it was difficult to make a comparison.

It appears that the flame spread in the tunnel can be considered to be an extension of the burner flame due to the total rate of fuel production along the specimen up to the end of the flame extension. The total rate of fuel production depends (1) on the rate of heat release of the material as a function of incident flux and (2) the distribution of incident flux along the specimen up to the end of the flame extension. It is necessary to know the flame distance, burner flame plus flame extension, required to burn all of the fuel from the burner and the specimen. The burner flame is 1.4 m (4.5 ft) long and the flame extension is plotted as a function of the total fuel production from the specimen in figure 33 for all of the 0.92-m (3-ft) specimens tested. This includes all of the materials listed in table 3. The fuel production was determined by multiplying the average heat release rates measured in the tunnel by the specimen area of 0.42 m<sup>2</sup> (4.5 ft<sup>2</sup>). Also included in the plot are the values for a red oak deck where the flame distances are those reported as the flame progressed down the tunnel and the fuel production rate was determined from the oxygen depletion in the duct at the time each of these distances were reached. The oxygen depletion was converted to fuel production by use of equation (11). The points for methane were taken from figure 23 where the flow rate was converted to fuel production by assuming 34 J/cm<sup>3</sup> (912 Btu/ft<sup>3</sup>) of gas.

While there is an appreciable scatter of the points, they can be represented, to within  $\pm 25$  percent with some exceptions by the empirical equation,

$$d = (0.61 + 49 Q) \text{ meters} = (2 + 0.17 Q) \text{ feet} \quad (13)$$

where  $d$  is the flame extension and  $Q$  is the total rate of heat production in MW when SI units are used and Btu/sec when engineering units are employed.

There is no reason at the outset to assume that all of the materials would fall on a single curve. When the properties of the individual materials are properly taken into account, the relationship between the flame extension and the heat release rate should be considerably improved. Nevertheless equation (13) may still be adequate for the preliminary stage of the model development.

The most significant deviation from the curve is exhibited by the P.R. Polyurethane "O" which has an FSC 1735. There are several possible explanations. It produces a very large soot deposition in the tunnel which can obscure the maximum flame spread

distance or may oxidize on the surface by non flaming combustion to produce additional heat without an increase in flame length. The copious rate of volatile production may reduce the oxygen concentration in the duct by dilution and thus result in a false contribution to the estimated heat release. It is noted that if the heat release rate of  $12 \text{ W/cm}^2$  ( $11 \text{ Btu/ft}^2\cdot\text{sec}$ ) observed with the NBS heat release rate calorimeter were correct, the total heat release rate would be  $50 \text{ kW}$  ( $47 \text{ Btu/sec}$ ) and the point would be within the 25% range for the curve.

An interesting feature of equation (11) is that the flame extension reaches  $0.6 \text{ m}$  ( $2 \text{ ft}$ ) beyond the normal burner flame as soon as a significant amount of fuel is produced. This would appear to set an FSC of 10 as essentially the lower limit of the flame classification range. This phenomenon takes place because although the designated flame distance for the burner is  $4.1 \text{ m}$  ( $4.5 \text{ ft}$ ), based on the presence of the flame about 50% of the time, pulsating flamelets do occur as far as  $2.0 \text{ m}$  ( $6.5 \text{ ft}$ ). A very small amount of specimen fuel added to the burner fuel is required to bring the called distance out to  $2.0 \text{ m}$  ( $6.5 \text{ ft}$ ) resulting in the minimum flame extension of  $0.61 \text{ m}$  ( $2 \text{ ft}$ ) observed in figure 33. It should be pointed out, however, that values of the FSC between 0 and 10 have been reported in special cases.

It would be convenient to replace the visual observations of the flame distance in the tunnel by a thermocouple measurement. This would be a viable alternative if the gas temperature in the neighborhood of the maximum flame distance were a fixed quantity. Figure 34 shows the measured air temperature  $25 \text{ mm}$  ( $1 \text{ in}$ ) below the ACB at the called flame distance for all of the materials which were exposed in  $0.92\text{-m}$  ( $3\text{-ft}$ ) lengths. The figure illustrates the fall-off of this temperature with distance and with different classes of materials. However, it does portray an interesting distinction between the behavior of the cellulosic and the plastic materials that might be useful to examine later. The higher rate of fall-off with distance may be related to radiation losses due to their high smoke concentration. Due to differences in thermal conductivity between the test material and ACB, the temperatures would be somewhat different for full length specimens even when the flame distances are the same.

#### 4.4. Combustible Specimens of Standard Length

##### 4.4.1. General

The full length specimens actually tested on this project were limited to red oak, a high flame spread foam plastic ("O"), and two low flame spread foam plastics ("A" and "B"). However, non-instrumented tunnel runs were made on all of the materials used in the UL full-scale test series [6]. All of the normal data, which included distance versus time, temperature at  $7.0 \text{ m}$  ( $23 \text{ ft}$ ), and smoke transmission in the duct, taken on that program were available to this project.

#### 4.4.2. Flame Distance

Figure 35 shows the flame spread distance versus time for 7.9-m (24-ft) specimens of some representative materials: Oak ("AE"), treated plywood ("G"), a high FSC foam plastic ("O"), and a low flame spread foam plastic ("A"). These data were taken during regular uninstrumented tunnel tests. Although material A has a low FSC because of its short flame distance, it reaches this distance in a very short time. If this time or the initial slope were reported as well as the FSC there should be less misunderstanding about the short buildup time of this material in a room fire. The extent of this buildup would depend on the size of the ignition source in the room.

The question sometimes arises as to whether the flame is attached to the surface or simply burning in the upper volume of the tunnel. For many materials, including the treated cellulose, the separation of the flame from the surface is clearly seen. However, there is some tendency to think of the flame spreading along untreated wood products as being attached. In order to shed some light on this question, 0.25 mm (10 mil) alumel chromel thermocouples were attached to the surface of a red oak deck at 0.61-m (2-ft) intervals along its length. The times at which the temperature reached 350 °C (660 °F), taken to be the temperature at which pyrolysis becomes rapid enough to support flaming, at each of the thermocouples is plotted in figure 36. This provides a distance versus time curve for the advancing pyrolysis front which is compared with the observed flame distance versus time curve. It can be seen that the flame leads the region of fuel production by an average distance of 1.5 m (5 ft), and thus is not attached to the surface in the region where its distance is measured.

#### 4.4.3. Temperature

Figure 37 shows the temperature versus time recorded by the fuel contribution thermocouple at 7.0 m (23 ft) during regular tunnel runs. Note that the treated plywood ("G") results in a higher temperature than that of ACB while the foam plastic ("B") has a slightly lower temperature. The high FSC foam ("O") has an even lower temperature at 10 minutes. This apparent anomaly may be due to the increase in radiation losses of the smoke laden air when the plastic specimen is present. Note that the peak temperature of the type "O" foam plastic occurred in two minutes while the flame spread over the end of the tunnel in 19 seconds.

In figure 38 the temperature distribution along the wall and floor at 4.3 m (14 ft), is shown at two minutes for a full length type B specimen. The maximum flame spread distance was 3.1 m (10 ft). Note that a 204 °C (400 °F) surface radiates about 0.3 W/cm<sup>2</sup> (0.26 Btu/ft<sup>2</sup>·sec).

The air temperature profiles are compared at 2.7 and 4.9 m (9 and 16 ft) for full length specimens of B and ACB in figures 39 and 40. The flame distance was 3.2 m (10.5 ft) for B.



#### 4.4.4. Oxygen Concentration

The oxygen concentration at floor level in the tunnel at 3.1 and 5.5 m (10 and 18 ft) for a low FSC foam plastic is shown in figure 41. The depletion is quite small particularly at 3.1 m (10 ft) where it is less than three percent. Since the maximum flame spread distance was 2.9 m (9.5 ft), the oxygen depletion is not seen to be a limiting factor. Figure 42 shows the oxygen concentration at the ceiling and floor locations for the same material at 6.7 m (22 ft) in the tunnel. The oxygen depletion of nine percent at the floor level was similar to that at 5.5 m (18 ft). Just under the specimen it was up to 31 percent. The oxygen depletion ahead of the flame traveling up a wall or across a ceiling in a room would also be expected to be high.

Figure 43 shows the oxygen concentration in the duct for a red oak deck. This deck which had been constructed for an earlier test flamed over in 3.6 minutes. The high FSC was attributed to a loosening up of the deck due to drying during the three-week delay. The flameover time is indicated on the chart. There was a depletion of 25 percent at the time of flameover.

The depletions at the floor of the tunnel at 3.1 and 5.5 m (10 and 18 ft) for the oak are shown in figure 44. Even at 5.5 m (18 ft) the depletion on the floor is only eight percent. On the ceiling at 6.7 m (22 ft) the depletion reaches 69 percent at the time of flameover as seen in figure 45 and becomes nearly complete by the end of the 10-minute test.

Even on the floor of the tunnel the oxygen depletion becomes essentially complete in the case of the 1735 FSC foam plastic as seen in figure 46. At the time of flameover the depletion at 5.5 m (18 ft) was 26 percent on the floor. While this oxygen depletion is high, it does not prevent the flame from spreading over the end of the tunnel in 19 seconds.

#### 4.4.5. Air Velocity

The output voltage of the thermoanemometer at the entrance slit is shown in figure 47 for a full length type "O" specimen (F.R. Polyurethane with FSC 1735). After the initial drop and recovery characteristic of a non-combustible specimen, there was a measurable drop of 25 percent in the velocity by the end of the test. This is taken to be the approximate drop in the volumetric rate of air inflow to the tunnel. It will not be exactly that since there could be some change in the velocity distribution across the slit or in the contraction factor at the location of the probe. There was a 12 percent reduction by the time of flameover. The data curves for the full length oak and type B (F.R. Polyurethane with FSC 28) specimens did not show a measurable drop in the inlet velocity. Because of the low time resolution the velocity distribution was not measured in the tunnel for the combustible specimens.

#### 4.4.6. Burning Rate

The average rate of weight loss per unit area as a function of distance along the type B specimen was determined by cutting it up into sections of 0.31 m (1 ft) or less in length after the test. The residual weight was subtracted from the original weight which was calculated from the average density of the specimen determined before the test. This difference was divided by the five-minute exposure time during the test and the exposed area of the specimen. The results are plotted in figure 48. This curve shows the origin of the fuel in relation to the area exposed by the burner and the reported flame spread distance which was 3.1 m (10 ft) in this particular test. There is an abrupt change in the average fuel production rate at the called flame distance as one would expect. In order to demonstrate that the flame did not stop in the tunnel due to burn through of the specimen, the minimum thickness of decomposed material was measured at each distance. These thicknesses were subtracted from the original 5-cm (2-in) thickness of the specimen and are plotted in figure 49 to show the distribution of the depth of the decomposed material with distance in the tunnel.

#### 4.4.7. Smoke

The optical transmission in the duct for a full length type B (F.R. Polyurethane with FSC 28) specimen dropped almost to zero immediately upon ignition and then began to rise fairly rapidly to a plateau at 60 percent. After three minutes it rose again to 87 percent. These two transmissions are equivalent to optical densities per meter of 0.54 and 0.15. These calculations are based on an optical path length of 0.41 m (16 in). The initially high optical density could not be determined because the light transmission had been recorded on a linear instead of a log scale.

#### 4.5. Effect of Air Velocity on Flame Spread in the Tunnel

Table 5 shows the effect of velocity on the flame spread distances observed in the tunnel for three low flame spread foam plastics over a range of 0.5 to 1.6 m/s (95 to 312 ft/min). This experiment was run as part of the UL full-scale test program [6]. Going up or down in air velocity did not result in over a 0.31-m (1-ft) difference in flame spread distance and there was no established trend toward an increase or decrease in this distance. The independence of the distance on the air supply rate indicates that oxygen depletion was not a limiting factor in the maximum flame spread distance of these materials.

#### 4.6. Effect of Ceiling-Wall Mounting of Specimens in the Tunnel

It is readily observed in corner tests [6] that the flame usually spreads further and more rapidly along the intersection between the wall and ceiling than it does over the regions of the ceiling surface remote from a boundary. This corner effect may be due in part to radiation trapping and in part to the concentration of the fuel generated there. In any case this effect, which is important in the room fire buildup process, is demonstrated in the tunnel, as seen in table 6. When the back wall,

Table 5. Flame Distance in the Tunnel Versus  
Air Velocity for Three Low FSC Foam Plastics

Material *	Velocity (ft/s)	Distance** (ft)
A	95	9.0
A	177	8.5
A	240	8.5
A	240	9.0
A	240	9.0
A	312	7.5
B	95	10.0
B	177	9.0
B	240	9.5
B	240	9.5
B	312	9.0
C	95	8.5
C	177	9.0
C	240	9.5
C	240	10.5
C	312	9.5

\* See description in table 3, page 25.

\*\* 1 foot = 0.305 meters

opposite the window, as well as the ceiling was lined with the specimen material the spread distances were generally increased and the flameover times decreased. In the most dramatic case the plastic foam labeled "S" (F.R. Polyisocyanurate with FSC 26) had a flame distance of 2.9 m (9.5 ft) in the standard test, qualifying it for an FSC 25, but flamed over the end in 20 seconds in the ceiling-wall configuration. These tests were not instrumented and were not performed as a part of this project, but as part of the UL full-scale test program referred to earlier. However, because of their importance to the considerations of this investigation the results are reported here.

Tentatively it appears that the flame spread properties of a material in a room away from an intersection of two walls or a wall and the ceiling may be characterized by the data obtained during a standard tunnel test but not necessarily by its FSC rating. If the fire buildup in a room is strongly influenced by the enhanced flame spread in the neighborhood of an intersection then perhaps the ceiling-wall configuration should be included along with the ceiling only mounting in the tunnel tests.

The results in table 6 constitute another argument against the concept of oxygen starvation as a controlling factor in the flame spread distance in the tunnel, since increasing the amount of material increases the distance of spread.

Table 6. Effect of Ceiling-Wall Mounting on Distance and Time in the Tunnel

Code	Standard FSC	Material Identification	Distance (ft)*		Flameover Time (s)**	
			Standard	Corner	Standard	Corner
T	18	F.R. treated wood particle board	8	8	—	—
I	18	F.R. treated wood fiber board	8	17	—	—
A	22	F.R. Polyisocyanurate	8.5,9,9	11	—	—
G	23	Treated plywood	9	over	—	350
R	26	Foil faced F.R. Polyisocyanurate	9.5	9.5	—	—
S	26	F.R. Polyisocyanurate	9.5	over	—	20
B	28	F.R. Polyurethane	10	over	—	100
C	28	F.R. Polyurethane	9.5,10.5	over	—	226
J	54	Untreated wood fiber	15	over	—	175
AE	100	Red Oak flooring	over	over	330	166
U	156	Untreated wood particle board	over	over	212	133
H	178	Prefinished luan plywood	over	over	185	100
D	925	F.R. Polyurethane	over	over	44	69

\* 1 foot = 0.305 meters

\*\* Time at which the flame passes the end of the tunnel

## 5. SUMMARY

The present report describes the heat flux, oxygen concentration, temperature, velocity, and pressure measurements made in a series of instrumented tunnel tests. The two most important considerations regarding the environment in the tunnel are the heat transfer to the specimen surface and the availability of oxygen. The temperature and velocity profiles and the smoke density provide insight into the convective and radiative heat transfer mechanisms. Pressure measurements relate to the air velocity and its variation during the test.

The pressure distribution along the length of the tunnel indicated that most of the pressure drop takes place in the region of the entrance slit. Thus, the change in flow resistance in the hot region of the tunnel during the test has only a mild effect on the mass inflow velocity. The actual magnitude of the velocity change during a test is, however, dependent on the relative elevation and distance of the pressure taps in the exhaust duct beyond the tunnel, which varies from one tunnel installation to another. This variation is probably responsible for some of the differences in smoke data on the same material measured in various tunnels. The largest drop in the inflow velocity observed during these tests was 25% for a FSC 1735 polyurethane foam. There was a 12% reduction by the time that the flame spread over the end of the tunnel.

The heat transfer to the exposed surface of the specimen in the tunnel was measured with the following: (1) heat flux meters, (2) deduced from the temperature distributions along the length of the exposed and unexposed surfaces of an asbestos mill-board specimen, and (3) deduced from the temperature and velocity profiles at various locations in the tunnel. The maximum observed heat flux from the burner was  $6.3 \text{ W/cm}^2$  ( $5.5 \text{ Btu/ft}^2\cdot\text{sec}$ ) measured with a water-cooled flux meter flush with the surface of an asbestos-cement board specimen and  $0.61 \text{ m}$  ( $2 \text{ ft}$ ) downstream of the burner. This flux was continually increasing during the whole ten-minute test period. Heat fluxes of  $6.0$  to  $8.4 \text{ W/cm}^2$  were observed in the U.L. corner tests at the time the ceiling became fully involved [6]. The heat flux falls off rapidly in the tunnel with distance. Where differences in the performance of materials in the tunnel and in the room are observed it is reasonable to attribute it in part to the different incident heat flux distributions. More data are needed on the incident fluxes in a room fire to make quantitative comparisons. The heat flux distributions in the room will depend on the size of the flame from the ignition source and also on the room geometry. Thus, one cannot say in general whether the tunnel represents too mild or too severe an exposure. The total incident heat flux deduced from the temperature rise of an AMB specimen at  $0.61 \text{ m}$  ( $2 \text{ ft}$ ) was  $4.2 \text{ W/cm}^2$  ( $3.7 \text{ Btu/ft}^2\cdot\text{sec}$ ). The incident heat flux distribution is a strong function of distance, falling to roughly half of its maximum value at the end of the flame, and will vary significantly with the thermal conductivity of the specimen. The difference in the incident heat flux levels deduced from the temperatures measured on the AMB and that measured by the water-cooled heat flux meter are qualitatively accounted for by the difference in surface temperatures between the flux meter and the specimen. Radiation losses from the smoke-laden gases were evidenced by the reduction in temperature at the fuel contribution thermocouple and by the increased heat flux measured on the floor of the tunnel for materials yielding high smoke densities.

Even in the absence of radiation from the smoke particles the rate of heat absorption in the specimen and in the walls and floor of the tunnel are as much as 60% of the rate of heat production. These high heat transfer rates which depend strongly on the thermal properties, flame spread properties, and the smoking tendency of the specimen, make the temperature registered by the fuel contribution thermocouple at the end of the tunnel a poor measure of the heat release.

The reduction in the oxygen concentration does not appear to be a factor in limiting the flame distance in the tunnel for the materials examined on this project based on the following evidence:

- (1) The flame distance was not a marked function of the inlet air velocity over a range of  $0.5$  to  $1.6 \text{ m/s}$  ( $95$  to  $312 \text{ ft/min}$ ) for the three foam plastics tested.
- (2) The oxygen concentration on the floor of the tunnel at  $3.1 \text{ m}$  ( $10 \text{ ft}$ ), which was at the called flame distance for the FSC 28 F.R. Polyurethane foam being tested, was only reduced to 20.3 percent. It was reduced to 19.3 percent at the same location at the time of flameover for a foam plastic with an FSC of 1735 which flamed over the end of the tunnel in



19 seconds. A red oak specimen which flamed over the end of the tunnel in 3.6 minutes had an intermediate value of 19.7 percent at the same place at the time of flameover. A high oxygen concentration of oxygen in the air away from the flames in a well ventilated room fire. (The short flameover time for the red oak was attributed to a loosening of the joints in the specimen which had been stored for three weeks.)

- (3) The fact that the flame spread distances for low FSC materials were nearly the same for 7.9-m (24-ft) and 0.92-m (3-ft) specimens, even though the leading edge of the flame was adjacent to an ACB surface in the latter case, indicated that local conditions near the flame front were not controlling factors in the extent of the spread. (It is clear that the flame spread distance recorded in the tunnel is a flame extension rather than a surface flame spread.)
- (4) Increasing the exposed area of the material as was done in the ceiling-wall mounting tests led to increased flame spread distances.

The oxygen depletion measured in the exhaust duct was proportional to the heat release rates of the specimens. The flame spread distance is roughly proportional to the total rate of heat production in the tunnel. The flame spread distance, for those materials whose flames terminate within the tunnel, can be considered to be an extension of the burner flame due to the fuel generated by the specimen primarily in the region of the burner flame. Thus an FSC 25 material which spreads flames from 1.4 m (4.5 ft) to 2.9-m (9.5 ft) exhibited essentially the same flame spread distance when the specimen material was limited to the region between 0.3 and 1.2 m (1 and 4 feet).

The flame extends beyond the pyrolyzing region for those materials that spread flame over the end of the tunnel. The maximum flame spread distance led the forward extent of the pyrolysis region by about 5 feet over the whole length of the tunnel for red oak. The fuel required for flame propagation comes from the region already covered by flame, not the region ahead of it.

The data presented in this report are taken from a wide variety of tests rather than from repeated experiments aimed at statistical accuracy. However, there is no reason to suggest that repeated experiments would lead to greatly different results. The intention was to provide a large scope of information which must be taken into account in constructing an analytical model of the Steiner tunnel and to make suggestions that might be considered in improving the usefulness of the E 84 tunnel test. When particular areas have been identified for critically testing the theory against experiment, some measurements similar to some of those described in this report will need to be run more carefully and be repeated several times.

## 6. RECOMMENDATIONS

The following recommendations are presented for consideration as a result of the research described in this report.

1. The oxygen depletion in the duct beyond the tunnel could provide an approximate measure of the rate of heat production by the specimen. It is suggested that an oxygen analyser could be included in the standard tunnel test. This measurement is not affected by the heat losses in the tunnel, as is the temperature recorded by the fuel contribution thermocouple. However, the mass flow rate into the tunnel must be constant or known. A knowledge of the fuel contribution is important for research as well as regulation. This is not offered as a substitute for the heat release rate calorimeter which measures the heat release rate under well-defined and controlled conditions. However, it would be a considerable improvement over the present fuel contribution measurement in the tunnel.
2. The value of the smoke measurement in the tunnel could be vastly improved simply by recording the optical density rather than the absorptivity of the smoke. The optical density of the smoke generated in the tunnel could be compared directly with the optical density of the smoke emerging from a room. It would have the advantage of measuring the optical density of a dynamic rather than a static system as is measured in the smoke density chamber. However, it might be necessary to measure the smoke closer to the end of the tunnel to avoid losses due to deposition. Again this modification is not suggested as an alternative to the smoke density chamber in which the exposure conditions are controlled. It is offered as an improvement over the present system and does offer a more realistic range of exposures than the smoke density chamber. While the present project was primarily concerned with flame spread, a knowledge of the optical density of the smoke in the tunnel is an essential ingredient in accounting for radiation heat losses. These losses affect the heat transfer to the specimen and thus its flame spread.
3. In principle, shifting the airflow control from the pressure drop at the exhaust duct to the inlet air velocity as measured with an anemometer at the entrance slit would ensure a constant mass flow rate of air through the tunnel during a test. The extent of its present variation through a test depends on the temperature increase of the exhaust gases as well as on the construction features of the tunnel particularly the relative height of the tunnel and the pressure tap, the distance of the tap from the tunnel, and the height of the entrance slit. While the indications are that the air velocity has only a minor effect on the maximum flame spread distance it is a significant factor in the smoke measurement.

Any control system for inlet air velocity must be suitably damped to avoid oscillations of the control mechanism due to turbulent fluctuations in the incoming air.

It has been suggested by W.J. Christian [14] that the constant mass flow could be achieved by moving the pressure tap upstream of the burner where only ambient temperature air is involved. Since most of the pressure is dropped across the entrance region of the tunnel as seen in figure 17 this seems to be an attractive alternative to the location of a velocity probe at the entrance slit. (This method has been adopted in ASTM E 84-76a.)

4. Although it appears to be the general practice at the time of this research to measure the air velocity of 1.2 m/s (240 ft/min) at an air temperature of 41 °C (105 °F) at the end of the tunnel, this should be so written in the standard to provide consistency between operators. However, because of temperature gradients in the tunnel at elevated temperature, it would be better to specify that the velocity be measured at ambient temperature. A velocity of 1.2 m/s (240 ft/min) at 20 °C (68 °F) represents a seven percent greater mass flow rate than 1.2 m/s (240 ft/min) at 41 °C (105 °F).
5. The new method of measuring the FSC (ASTM E 84-76a) is based on the area under the distance versus time curve. In order to evaluate the potential for rapid fire buildup in low density materials, the time to ignition and the initial slope of the distance versus time curve should be quoted along with the new FSC. In order to show the potential for maximum extent of fire buildup, the maximum value of the flame spread distance should also be quoted. Neither flame spread distance nor flame spread rate can be determined from the new FSC index.
6. Observation of the maximum flame spread distances for 0.92-m (3-ft) specimens might be an auxiliary use of the tunnel. It appears that for materials with FSC 25 or less, the measured flame spread classification would be the same for a 0.92-m (3-ft) specimen as for a 7.9-m (24-ft) specimen; Much less material would be needed for a test. Furthermore, 0.92-m (3-ft) specimens of the high FSC materials tested on this project have flames which terminate within the tunnel, thus providing a basis for comparing all of the materials on a flame distance scale. This cannot be achieved with 7.9-m (24-ft) specimens. The flame distances in the tunnel may relate to the maximum fire buildup area in a room for a small ignition source. It should be noted, however, that the maximum fire buildup area in a room also depends on the size of the ignition source so that a material with a FSC 25 might produce flameover or flashover in a room if the ignition source is of sufficient size. In fact, the flame travel distances for 0.92 m specimens might rank materials with regard to the size of ignition source needed for flashover. The shorter the distance, the larger the ignition source required.

7. While the flame spread distances could be compared using 0.92-m (3-ft) specimens as discussed in the last paragraph, the flame spread times could be compared by recording the times at which the flame passed the end of the 2.4-m (8-ft) specimens of all of these materials. While there may be an economy to using 2.4-m (8-ft) specimens, the 2.4-m (8-ft) mark along the 7.9-m (24-ft) specimens used for the FSC determination would do as well. These spread times would be indicative of the speed of fire buildup in a room. Flames will spread past 2.4 m (8 ft) for all materials with FSC greater than 18.
8. Measurements made with the ceiling-wall mounting could augment the standard tunnel tests by indicating the flame spread potential of the material in the neighborhood of the intersection between the walls or between a wall and the ceiling. It is possible that the extent of the flame spread under the enhanced incident flux conditions in these areas could make the material more hazardous with respect to flame spread than the standard tunnel test would indicate.

#### 7. ACKNOWLEDGMENT

This research was conducted while the author was serving as a Research Associate at Underwriters' Laboratories, Inc. at Northbrook, Illinois in 1974. I am indebted to the management at UL for making the Steiner tunnel available on the occasions that it was needed and for providing the technical assistance necessary to pursue this project. Many individuals at UL contributed toward its success. In particular I appreciate the encouragement in this work that I received from Tom Castino and Jim Beyreis, the assistance that I got from Bill Metes and Tom Perdue in running the instrumented tunnel tests, and the helpful discussions with Joel Lipsey on the background of the tunnel and the practical considerations concerning its operation.

The crucial element of this project was the instrumentation and its interfacing with the tunnel. For this I am greatly indebted to Dick Bieniarz and his crew, particularly Stan Lesiak and Joe Mack.

I also wish to thank Dan Gross whose thorough review of the original draft led to a considerable improvement of the final version of this report.

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U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET		1. PUBLICATION OR REPORT NO. NBS TN-945	2. Gov't Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE  AN INVESTIGATION OF THE FIRE ENVIRONMENT IN THE ASTM E 84 TUNNEL TEST			5. Publication Date August 1977	
			6. Performing Organization Code	
7. AUTHOR(S) William J. Parker			8. Performing Organ. Report No.	
9. PERFORMING ORGANIZATION NAME AND ADDRESS  NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234			10. Project/Task/Work Unit No. 4926680	
			11. Contract/Grant No.	
12. Sponsoring Organization Name and Complete Address (Street, City, State, ZIP)  same as No. 9			13. Type of Report & Period Covered Final	
			14. Sponsoring Agency Code	
15. SUPPLEMENTARY NOTES				
16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.) Measurements were made of heat flux, oxygen concentration, temperature, velocity and pressure in a series of instrumented ASTM E 84 tunnel tests using (1) standard length specimens, (2) 0.91-m (3-ft) long specimens, and (3) a reference specimen consisting of asbestos-cement board and an auxiliary controlled supply of methane. Five different flow rates of methane to the auxiliary burner provided constant and known heat inputs simulating the gaseous decomposition products from regular test specimens. Incident heat fluxes on an inert specimen surface as high as 6.3 W/cm <sup>2</sup> (5.5 Btu/ft <sup>2</sup> ·s) were measured within the flame impingement zone with a water-cooled heat flux meter 0.61 m (2 ft) downstream from the burner. While oxygen depletion in the tunnel did not appear to be a dominating factor in controlling the flame spread, the oxygen depletion measured in the exhaust duct beyond the tunnel correlated with the total rate of heat production of the specimens. It appears that the differences in the observed burning behavior of materials in the tunnel test and in a room may be mainly due to differences in the incident heat flux distribution in the two cases. These distributions reflect the different geometries, orientations, and ignition sources. The potential for rapid flame spread of some low flame spread classification (FSC) low density materials is evident from observations of the flame propagation along these materials during the tunnel test, but is not adequately reflected in the flame spread classification.				
17. KEY WORDS (six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons) ASTM E 84; fire tests; flame spread; heat flux; heat release rate; smoke; Steiner Tunnel Test; oxygen depletion.				
18. AVAILABILITY <input checked="" type="checkbox"/> Unlimited  <input type="checkbox"/> For Official Distribution. Do Not Release to NTIS  <input checked="" type="checkbox"/> Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402; <u>SD Cat. No. C13-40: 945</u>  <input type="checkbox"/> Order From National Technical Information Service (NTIS) Springfield, Virginia 22151			19. SECURITY CLASS (THIS REPORT)  UNCLASSIFIED	21. NO. OF PAGES  75
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## APPENDIX 8

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## MEMORANDUM

DATE: February 17, 1978

TO: Questionnaire File - Toczek & Sons  
 Manufacturing

FROM: Stephen F. Sims, Special Assistant

SUBJECT: Summary of Questionnaire to Purchasers  
 of Toczek & Sons Portable Insulation  
 Manufacturing Plant

The Subcommittee sent 102 questionnaires to persons identified in records furnished by Toczek & Sons Manufacturing as having ordered a T 1610 cellulose manufacturing machine. 68 persons or companies responded, 55 of whom had actually attempted to operate their machine. The results of the questionnaire are summarized below.

Profit and Output

Toczek & Sons promotional pamphlet states on the cover that the owner of the T 1610 machine can earn a profit as high as \$300 per day. Inside the brochure, the profit potential is increased to \$400. These figures, according to a footnote, are based on production of 300 pounds of insulation per home, for an eight hour day, at a selling price of .228¢ per pounds, and do not include taxes. On the back page, the maximum production capacity of the machine is identified as 300 pounds per hour.

Not one respondent reported attaining an output of 300 pounds per hour for an 8 hour day. Most of the owners reported much less. 25 complained specifically about the disparity between Toczek's advertising and their output.

Not one respondent said they earned \$400 per day before taxes. One respondent grossed \$4,162 for 12 jobs, which averages \$347 per job. However, this producer bagged his product and did not blow it into the house until he had produced the total amount needed. Naturally, the time to blow cellulose into the house was not great, but the time spent producing and bagging the cellulose would also have to be added in.

Over 40 of the respondents reported that they grossed \$150 per day or less, and over 20 indicated that they had either no profit or virtually no production. The purchasers reported a total of 470 buildings insulated.

### Chemicals

Virtually all the producers used a mixture of 50% borax and 50% aluminum sulfate, which is recommended and sold by Toczek & Sons. The volume of chemical in the finished product was typically between 20 and 33% by weight, although in a few instances more chemical was used. Many of the respondents were unsure of the exact ratio of chemical to paper and simply reported the 25-75 ratio cited by Toczek.

### Tests

The questionnaire asked the manufacturers for copies of any tests on their product by independent laboratories, or approvals granted by government agencies. A number of manufacturers enclosed a copy of a U.S. Testing Service report performed on a cellulose sample supplied by Thermolator (a Toczek subsidiary). Many thought that this test, which was provided to them by Toczek & Sons, was also valid for cellulose produced from their machines. At least two manufacturers indicated to the Subcommittee that Stanley Finkel told them that this was the case. Perhaps because of this situation, Toczek & Sons sent a letter (attached) dated December 1, 1977, to all T 1610 owners advising them that the U. S. Testing Company results did not apply to their machine.

The Subcommittee could not find any T 1610 owners who had submitted their product for the HH-1-515C tests by an independent laboratory. One manufacturer, Mr. Jonathan Ball of Parma, Idaho, got on the approved list of both Idaho Power and the Boise City Housing Authority on the strength of the Thermolator lab test. Mr. David Howard of Madison, Wisc, was similarly approved by

Madison Gas and Electric. Another owner, Russel Crews of Richardson, Texas, provided a sample for testing to Dallas Power and Light. According to Dallas Power and Light officials, the sample passed a flame spread test, but did not undergo the full range of tests called for in HH-1-515C. Mr. ~~R. Koss~~ of Armor Insulation, Nanticoke, Pennsylvania, reported an R value of 3.75 from Dynatech Laboratory. In sum, none of the manufacturers have passed a corrosion test.

Attachment

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BERNARD J. WUNDER  
 MINORITY COUNSEL

Dear \_\_\_\_\_:

This Subcommittee is investigating certain aspects of the cellulose insulation industry.

Your name has been furnished the Subcommittee by Toczek and Sons Manufacturing of Denver, Colorado, as a purchaser of their T1610 portable insulation manufacturing plant.

Pursuant to the authority granted to it by the Rules of the United States House of Representatives, the Subcommittee requests that you complete and return within ten days the enclosed questionnaire relating to your use of the Toczek portable insulation manufacturing plant.

Any questions relating to this official inquiry should be addressed to Subcommittee staff members John Galloway or Steve Sims at (202) 225-5365.

Thank you for your cooperation with the Subcommittee.

Sincerely,

JOHN E. MOSS  
 Chairman  
 Subcommittee on  
 Oversight and Investigations

JEM:jgm  
 Enclosure

REPLY \_\_\_\_\_  
 \_\_\_\_\_

APPROVAL \_\_\_\_\_  
 \_\_\_\_\_



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QUESTIONNAIRE TO PURCHASERS OF  
TOCZEK & SONS PORTABLE INSULATION MANUFACTURING PLANT

1. Your Name \_\_\_\_\_
2. Title \_\_\_\_\_
3. Company Name and Address \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_
4. Telephone Number \_\_\_\_\_
5. Date or Dates of Purchase of Toczek & Sons Portable  
 Insulation Manufacturing Plant, T1610 \_\_\_\_\_  
 \_\_\_\_\_
6. Have you found your machine satisfactory?  
       \_\_\_\_\_ Yes                      \_\_\_\_\_ No  
 If not, why not?  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Have you had any problems with your chemicals hardening  
 or feeding improperly? Has humidity affected your ability  
 to manufacture cellulose?  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

7. How much before taxes have you been able to earn per day through the operation of this machine?

---



---

8. Has Toczec & Sons supplied you with chemicals for use with this machine?

\_\_\_\_\_ Yes \_\_\_\_\_ No

If so, how many pounds and what chemical or chemicals?

---



---



---

9. Has Toczec & Sons provided you with the name or names of persons or companies who might be able to supply you with chemicals?

\_\_\_\_\_ Yes \_\_\_\_\_ No

If so, please indicate the name or names of such persons and the amount of chemical purchased.

---



---



---

10. What chemicals have you been using to manufacture cellulose insulation?

---



---

What percentage do you use of each chemical?

---



---

10. (cont'd)

What ratio of chemical to paper do you employ?

---

---

11. Have you had a sample of your product tested for flame spread, thermal properties, corrosiveness, etc., by a laboratory?

\_\_\_\_\_Yes \_\_\_\_\_No

If so, please provide a copy of all such laboratory reports.

12. Has your product been tested or approved by a Federal, State, or local government authority?

\_\_\_\_\_Yes \_\_\_\_\_No

13. Has your product been approved by a utility company?

\_\_\_\_\_Yes \_\_\_\_\_No

If so, please provide the name of the utility.

---

---

14. Are you satisfied that the machine sold to you by Toczek & Sons is capable of producing a quality product?

\_\_\_\_\_Yes \_\_\_\_\_No

15. What method do you use to assure a proper ratio of chemicals to paper in operating your portable insulation manufacturing machine?
- 
- 
- 

16. Do you periodically test the flammability of your product while it is being produced?
- 
-

17. Have you had any problems acquiring paper?

\_\_\_\_\_ Yes \_\_\_\_\_ No

What type of paper do you use?

---

---

18. Approximately how many homes did you insulate with this machine?

---

---

19. Additional Comments.

---

---

---

---

TO EXHIBIT E

**TOCZEK and SONS  
MANUFACTURING**Manufacturers of  
High Quality Insulation Machinery4920 NOME STREET  
DENVER, COLORADO 80239  
(303) 371-2786

December 1, 1977

TO: All T-1610 Owners

FROM: Stanley Finkel

RE: U. S. Testing Company Flame Spread Test

Please be advised that the U. S. Testing Company's Flame Spread Test, classification Smoke and Fuel Contribution, of April 22, 1977, pertained solely to our working model T-1610 and in no way guarantees or implies the same test results for your particular product.

If you follow identical procedures as we have with your machine similar results could be obtained. The reason we are informing you of our tests results is that we have been advised by our technical people that some of the users of the T-1610 deviate from the procedures we recommend, hence tests results will vary.

The tampering with adjustments on the machine in addition to substitution of suggested materials can cause great variation in your end product.

Yours truly,

Toczek & Sons

Stanley Finkel  
Vice President



TO EXHIBIT E  
TH-51

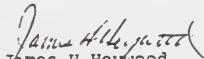
## United States Testing Company, Inc.

5521 TELEGRAPH ROAD, LOS ANGELES, CALIFORNIA 90040  
(213) 723-7181 • (213) 722-0608

## REPORT OF TEST

THERMOLATOR, INC.  
3750 Wheeling Str. Bldg. #5  
Denver, Colo. 80239FLAME SPREAD CLASSIFICATION;  
SMOKE AND FUEL CONTRIBUTIONCELLULOSIC, LOOSE-FILL  
INSULATION

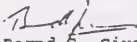
April 22, 1977

  
James H. Heywood  
Test Engineer

  
S. Elliott  
Test Technician

Page 1 of 11

Laboratories in: New York • Chicago • Los Angeles • Houston • Tulsa • Memphis • Reading • Richland

 IA 70232  
SIGNED FOR THE COMPANY  
BY   
Bernd S. Givon  
Professional Engineer

OUR LETTERS AND REPORTS ARE FOR THE EXCLUSIVE USE OF THE CLIENT TO WHOM THEY ARE ADDRESSED AND THEIR COMMUNICATION TO ANY OTHERS OR THE USE OF THE NAME OF UNITED STATES TESTING COMPANY, INC. MUST RECEIVE OUR PRIOR WRITTEN APPROVAL. OUR LETTERS AND REPORTS APPLY ONLY TO THE SAMPLE TESTED AND ARE NOT NECESSARILY INDICATIVE OF THE QUALITIES OF APPARENTLY IDENTICAL OR SIMILAR PRODUCTS. SAMPLES NOT DESTROYED IN TESTING ARE RETAINED A MAXIMUM OF THIRTY DAYS. THE REPORTS AND LETTERS AND THE NAME OF THE UNITED STATES TESTING COMPANY, INC. OR ITS SEALS OR INSIGNIA, ARE NOT TO BE USED UNDER ANY CIRCUMSTANCES IN ADVERTISING TO THE GENERAL PUBLIC.

SUMMARY OF TEST RESULTS

## A. Flame Spread Properties per ASTM E-84:

Because of the possible variations in reproducibility, the results are adjusted to the nearest figure divisible by 5.

## 1. For this sample of cellulosic, loose-fill insulation:

<u>Formula</u>	<u>Flame Spread Area</u>	<u>Fuel Contribution</u>	<u>Smoke Density</u>
15	15	0	5

## 2. The corresponding Building Materials Surface Burning Classifications are:

NFPA - Class A

UBC - Class I

<u>NFPA CLASS</u>	<u>UBC CLASS</u>	<u>FLAME SPREAD</u>
A	I	0 through 25
B	II	26 through 75
C	--	76 through 200
-	III	76 through 225
D	--	201 through 500
E	--	Over 500

BUILDING CODES CITED

1. National Fire Protection Association, NFPA No. 101, "Life Safety Code".
2. UNIFORM BUILDING CODE, Part VIII, "Fire Resistive Standard for Fire Protection".

Vol. I (1973), Chapter 42 - Interior Wall and Ceiling Finish, Sections 4201-4203.



UNITED STATES TESTING COMPANY, INC.

TH-52

LA 70232

SUMMARY OF TEST RESULTS (Cont.)

## B. Flame Resistance Permanency per ASTM C-739

The results reported are an average of three (3) determinations per test.

For this sample of cellulosic, loose-fill insulation:

<u>Char Length, in.</u>		<u>Heat Generation, °F</u>	
<u>Orig. Cond.</u>	<u>Aged</u>	<u>Orig. Cond.</u>	<u>Aged</u>
3.0	3.3	180	185

Percent Change: 9.1

2.7

COMMENT:

The submitted sample falls within the 20% maximum allowable change in char length after accelerated aging indicating its flame resistance permanency.

## APPENDIX 9



Corporate Headquarters  
 PO Box 1057R  
 Morristown, New Jersey 07960

Letter to Resellers  
 Aluminum Sulfate  
 Customer Letter

January 16, 1978

Dear Customer:

Concern has been expressed that aluminum sulfate used in the manufacture of cellulosic insulation can be corrosive to metal surfaces encountered in building structures.

An example of such concern is a report by the U.S. Energy Research and Development Administration (ERDA), dated January 1977, which states (i) that a substantial number of cellulosic insulation products (from unidentified sources) tested by ERDA exhibited varying degrees of corrosiveness per the ASTM (American Society for Testing and Materials) test method and (ii) that corrosion potential may be greatest when treated cellulose is in intimate contact with bare metal surfaces. The report also states that some separation of the additive chemicals (such as aluminum sulfate) from the cellulosic matrix occurred in 13 of the 19 samples ERDA surveyed. This suggests that the possibility exists for creating pockets of higher additive chemical concentrations when such treated cellulosic insulation is used, thereby creating a higher potential of corrosion.

We believe and the ERDA report indicates that if sufficient care is taken in the formulation, blending, and mixing of the cellulose product containing aluminum sulfate, this product can have acceptable corrosion properties.

In view of these circumstances, we think it is appropriate for us to review with you our knowledge of the properties of aluminum sulfate. Aluminum sulfate for this application is sold as a hydrated solid and in this state should be non-corrosive. When this aluminum sulfate comes in contact with water, however, the resultant solution will become acidic, with a pH which may go to approximately 2.5 without buffer. As such, this solution may be corrosive to metals. We have attached our latest Material Safety Data Sheet which describes additional properties for this product. We are also attaching a copy of a document entitled Complete Listing of Product Standards and Test Methods, which was prepared by NEMA (National

Mineral Wool Insulation Association, Inc.). TIMA (Thermal Insulation Manufacturers Association, Inc.), and NCIMA (National Cellulose Insulation Manufacturers Association, Inc.).

In light of the foregoing and to protect the public, you and ourselves, we shall require that each of our customers who resells aluminum sulfate for use in the production of cellulosic insulation deliver to us a certificate by February 15, 1978, in the form attached, that he will sell aluminum sulfate for such end use only upon first obtaining from his customer a certificate that this cellulosic insulation material will not be marketed unless the corrosiveness and other properties of the material comply in all respects with General Services Administration Specification HH-I-515C. Please note that the certification includes future amendments as well as subsequent federal specifications or regulations. Copies of the existing federal specification (adopted April 13, 1976, superseding HH-I-515B of September 25, 1972) and the ASTM standards referred to therein are enclosed.

We, of course, are not familiar with your customers' operations. We trust that, if you have not already done so, you will promptly obtain assurances from your customers that their insulation material complies with all applicable federal, state and local laws and regulations and that they have instituted quality control programs and safety measures which will ensure that the public is fully protected.

We hope that you will find the foregoing helpful, and we would appreciate your returning the enclosed certificate promptly to ensure continuation of supply.

In the absence of our receiving the certificate by February 15, 1978, we regret that we will be unable to continue deliveries after that date.

Sincerely,

Marketing Manager

Enclosure



Certification

We purchase aluminum sulfate from Allied Chemical Corporation ("Allied Chemical") for resale to manufacturers of cellulosic insulation. So that Allied Chemical may continue to supply aluminum sulfate for such use, we hereby certify to Allied Chemical that we will obtain, as a condition of sale to customers using aluminum sulfate for such use, a certificate from each such customer that finished cellulosic insulation material produced using aluminum sulfate purchased from Allied Chemical will not be sold for such end use unless such material consistently complies in all respects with the provisions of General Services Administration Specification HH-I-515C, Federal Specification-Insulation Thermal (Loose Fill for Pneumatic or Poured Application): Cellulosic or Wood Fiber, as may be amended (or other subsequent federal specification or regulation which may be applicable), relating to the corrosiveness and other properties of such material.

By \_\_\_\_\_  
An officer thereof \_\_\_\_\_

Dated: \_\_\_\_\_



Corporate Headquarters  
P.O. Box 1057R  
Morristown, New Jersey 07960

Letter to Users

Ammonium Sulfate  
Customer Letter

January 16, 1978

Dear Customer:

Concern has been expressed that ammonium sulfate used in the manufacture of cellulosic insulation can be corrosive to metal surfaces encountered in building structures.

An example of such concern is a report by the U.S. Energy Research and Development Administration (ERDA), dated January 1977, which states (i) that a substantial number of cellulosic insulation products (from unidentified sources) tested by ERDA exhibited varying degrees of corrosiveness per the ASTM (American Society for Testing and Materials) test method and (ii) that corrosion potential may be greatest when treated cellulose is in intimate contact with bare metal surfaces. The report also states that some separation of the additive chemicals (such as ammonium sulfate) from the cellulosic matrix occurred in 13 of the 19 samples ERDA surveyed. This suggests that the possibility exists for creating pockets of higher additive chemical concentrations when such treated cellulosic insulation is used, thereby creating a higher potential of corrosion.

We believe and the ERDA report indicates that if sufficient care is taken in the formulation, blending, and mixing of the cellulose product containing ammonium sulfate, this product can have acceptable corrosion properties.

In view of these circumstances, we think it is appropriate for us to review with you our knowledge of the properties of ammonium sulfate. Ammonium sulfate is sold as a solid and in the dry state should be non-corrosive. When the dry ammonium sulfate comes in contact with water, however, the resultant solution may become weakly acidic, with a pH which may go to approximately 5 without buffer. As such, this solution may be corrosive to metals. We have attached our latest Material Safety Data Sheet which describes additional

properties for this product. We are also attaching a copy of a document entitled Complete Listing of Product Standards and Test Methods, which was prepared by NMWIA (National Mineral Wool Insulation Association, Inc.), TINA (Thermal Insulation Manufacturers Association, Inc.), and NCIMA (National Cellulose Insulation Manufacturers Association, Inc.).

In light of the foregoing and to protect the public, to protect you and to protect ourselves, we shall require, prior to making any further deliveries, that each of our customers deliver to us a certificate, in the form attached, that the cellulosic insulation material to be produced containing our ammonium sulfate will not be sold for such end use unless the corrosiveness and other properties of the material comply in all respects with the General Services Administration Specification HH-I-515C. Please note that the certification includes future amendments as well as subsequent federal specifications or regulations. Copies of the existing federal specification (adopted April 13, 1976, superseding HH-I-515B of September 25, 1972) and the ASTM standards referred to therein are enclosed.

We, of course, are not familiar with your operations. We trust that your insulation material complies with all applicable federal, state and local laws and regulations, and that, if you have not already done so, you will promptly institute quality control programs and safety measures which will ensure that the public is fully protected.

We hope that you will find the foregoing helpful, and we would appreciate your returning the enclosed certificate promptly to insure continuation of supply.

In the absence of our receiving the certificate by February 15, 1978, we regret that we will be unable to continue deliveries after that date.

Sincerely,

Marketing Manager

Enclosures

Certification

We purchase ammonium sulfate from Allied Chemical Corporation ("Allied Chemical") for use in the manufacture of cellulosic insulation. So that Allied Chemical may continue to supply ammonium sulfate for such use, we hereby certify to Allied Chemical that the finished cellulosic insulation material produced using ammonium sulfate purchased from Allied Chemical will not be sold for such end use unless such material consistently complies in all respects with the provisions of General Services Administration Specification HH-I-515C, Federal Specification-Insulation Thermal (Loose Fill for Pneumatic or Poured Application): Cellulosic or Wood Fiber, as may be amended (or other subsequent federal specification or regulation which may be applicable), relating to the corrosiveness and other properties of such material.

\_\_\_\_\_  
By \_\_\_\_\_  
An officer thereof

Dated: \_\_\_\_\_

## APPENDIX 10

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Energy Conservation

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**Survey of Cellulosic Insulating  
Materials**

January 1977

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Robert W. Anderson  
Energy Research & Development Administration  
Division of Industrial Energy Conservation  
Washington, D.C.

Paul W. Crane, Inc.  
Naval Weapons Support Center  
Crane, Inc.



# Survey of Cellulosic Insulation Materials

## I. INTRODUCTION

The properties of commercially available cellulosic thermal insulation materials were evaluated to obtain base level data on the materials and to assess existing specification standards commonly used for testing and purchasing. Cellulosic material has been used for residential building insulation for several decades and currently represents an estimated 30-40 percent of that market (second only to fibrous glass insulation). Nevertheless, very little data about the properties of the product have been published. The results of this survey provide guidance to the manufacturer in the design and manufacturing control of the material; to specification organizations in re-evaluating and improving specifications; and to the consumer in selecting a product.

Cellulosic insulation is manufactured from waste paper products, such as newspaper. Its manufacture is simple, requiring only shredding and milling to convert it into a low-density, fluffy material and the addition of chemicals to provide flame retardancy. When bagged, the material is ready to be installed. Even installation is simple; it can either be poured or blown in place. Because of the relatively low capital cost required for production and the large profitable market for the material, it is estimated that there are over one hundred manufacturers operating throughout the country.

Cellulosic insulation has several advantages which could produce even greater future demand for the product. On the other hand, it has several potential disadvantages which could seriously affect the industry, if not corrected. When properly applied, cellulosic insulation has excellent thermal resistance properties, is manufactured from an inexpensive and readily available waste material, and requires little energy or petroleum base materials in its manufacture. It can currently compete favorably on a cost/performance basis with other insulation materials, and, as future energy costs increase, its competitive position will be enhanced. However, on the negative side, cellulosic insulation has received criticism alleging poor flame retardancy, overstated thermal resistance values and poor manufacturing quality control. Although it is suspected that some of these criticisms are justly deserved, there has been a lack of reliable data to refute or substantiate many of them.

In consideration of the above, this survey of cellulosic insulation properties, though limited in scope, provides base data which will prove valuable in providing a better understanding of the material, in improving the qual-

ity of the product, and in promoting the conservation of energy. The specific cellulosic properties addressed in this survey include:

- composition and quantity of fire retardant
- moisture absorptivity
- fire retardance
- thermal conductivity
- corrosiveness, and
- resistance to fungal growth.

## I. EXPERIMENTAL APPROACH

A total of nineteen different off-the-shelf samples of cellulosic insulation were obtained from four geographic areas: Colorado, Minnesota, Indiana, and Pennsylvania. All tests, except for thermal conductivity and fire retardancy, were performed under direct ERDA contract at the laboratories of the Naval Weapons Support Center, Crane, Indiana. The thermal conductivity and fire retardance test data were supplied to ERDA by an independent organization, and the sample materials used in their tests were also used in the Naval Laboratory tests.

Whenever possible, tests were performed in accordance with the American Society for Testing Materials (ASTM) specifications C739-73; Cellulose Fiber (Wood Base) Loose-Fill Thermal Insulation. The ASTM C739-73 specification is referenced in the Federal specification HH-1-515C Insulation Thermal (Loose-Fill for Pneumatic or Poured Application) Cellulosic or Wood Fiber, and is the basis for the National Cellulose Insulation Manufacturers Association (NCIMA) specification N-101-73, Standard Specification for Cellulosic Fiber (Wood Base) Loose Fill Thermal Insulation. In some tests, conditions were modified to gain additional information which will be discussed later in the text.

Because it was realized that one sample from each manufacturer might not fairly represent that manufacturer's product, manufacturers' identifications were not given in the report: the data were evaluated as a whole to determine trends and patterns.

## I. EXPERIMENTAL RESULTS

### A. FIRE RETARDANT ADDITIVES

Samples of cellulosic insulation were analyzed to identify the additives and their relative proportions. This was done by extracting the water soluble content of 5 gram samples and subjecting the residue to a series of analytic procedures described in Appendix A. No attempt was made to analyze for possible water insoluble additives. The analysis scheme included use of X-ray diffraction, atomic absorption, spectrographic and X-ray fluorescence and differential thermal analysis techniques. The analyses were considered to be semiquantitative because:

1. the samples contained various unknown compounds that were also water soluble, such as starches, inks and adhesives;

2. the degree of hydration of the original fire retardant compound was not known (the most probable was assumed); and
3. only that quantity retained within or on the cellulose was analyzed. As will be discussed in the next section, it was observed that some of the fire retardant had separated in most of the samples.

The results of the analyses did provide a measure of the kinds and relative proportions of fire retarding additives as shown in Table I. Also included in Table I are the pH\* values of the samples when contacted with water. The procedure for measuring pH is given in Appendix B.

These analyses showed that boric acid\*\* and ammonium sulfate were the most common additives and were used singly or in various combinations with other additives such as calcium sulfate, aluminum sulfate and sodium carbonate. Comparison of the pH values of the respective samples showed that the resulting pH was not always in accordance with the kind and quantity of the additives. Whereas this could be, in part, a result of inaccuracies in the quantitative analyses, it is also possible that impurities in the cellulose stock material contributed to the final pH.

#### B. SEPARATION OF FIRE RETARDANT ADDITIVES

Of the nineteen samples received for analyses, thirteen showed visible evidence that some of the fire retardant chemical had separated from the cellulosic matrix; quantities of the additives were found at the bottoms of the containers. Because each sample had undoubtedly been handled differently from the time of its manufacture, no attempts were made to measure the quantity of the separated material nor to determine the effects such separations may have on the properties of the samples. The referenced standard specifications (ASTM, Federal and NCIMA) do not include a test or requirement for non-separation of the fire-retardant additive.

#### C. MOISTURE ABSORPTIVITY

The nineteen samples were tested for water absorption in accordance with ASTM C739-73, section 10.5. According to that specification, weight gain should not exceed 15 percent. For the standard test, samples of approximately 100 grams were pre-conditioned at 50 percent relative humidity (R.H.) and 120°F to a constant weight. The samples were then exposed to 90 percent R.H. at 120°F for 24 hours and the weight gain recorded. In addition to the standard 24 hour tests, cumulative weight gain data were also obtained after 8 days and 15 days.

Since the ASTM C-739-73 procedure does not specify the sample configuration during testing, the samples were contained in 9" x 12" x 2½" open containers to allow a low-packing density similar to that found in attic installations. For several of the sample materials, additional test specimens were packed in either 1000 ml or 2000 ml beakers to evaluate the effect of different packing densities and configurations.

\* A measure of the relative acidity of samples; 7.0 indicates a neutral solution and decreasing values indicate increasing acidic activity.

\*\* The boron contents were reported as boric acid; however, the original compound may have been other boron compounds such as "borax."

TABLE I  
Composition and pH of Cellulosic  
Insulation Samples

Sample Identification	Total Water Solubles %	pH	Fire Retardant Chemical, %				
			Ammonium Sulfate	Boric Acid	Calcium Sulfate	Aluminum Sulfate	Sodium Carbonate
526-1	18	4.4	18	—	—	—	—
526-5	20	8.0	—	11	1	—	5
527-A	22	8.2	—	16	—	—	3
527-B	31	4.8	—	23	—	—	—
527-C	28	8.1	—	22	—	—	5
527-C1	24	8.2	—	20	—	—	5
527-D	22	8.0	—	13	—	—	5
527-E	26	4.5	26	—	—	—	—
527-F	21	5.9	—	10	5	—	2
527-G	19	4.4	19	—	—	—	—
527-H	21	7.8	—	16	3	—	1
527-I	20	5.0	—	4	1	—	—
535	24	7.4	—	17	4	—	—
562	22	3.7	18	1	2	—	1
563-4	24	4.0	—	10	—	7	2
563-5	19	7.7	12	4	1	—	2
563-6	17	5.9	—	4	6	—	—
563-7	23	6.1	—	5	8	—	—
593	17	7.7	—	—	—	17	—

The results of the moisture absorptivity tests are given in Table II and shown graphically in Figure 1.

Examination of these data show the following:

1. There was a wide range in moisture absorption between samples when tested in the low density configuration. After the standard 24 hour test, moisture gains ranged from 3.5 to 38 percent and six of the samples exceeded the 15 percent limit given in the standard specification.
2. The differences in moisture absorption increased with increasing time—some samples had moisture gains in the 75 percent range after 8–15 days exposure. Also, in some samples the moisture gains reached a maximum and then decreased. The mechanism for this behavior is not known, but may be a result of some moisture-induced separation of the fire retardants from the cellulose matrix.
3. Generally, samples containing primarily boric acid had lower, and acceptable, moisture absorptivities, whereas those containing primarily ammonium sulfate had excessive gains in moisture. The one sample containing only aluminum sulfate showed excessive moisture gains but less than those containing ammonium sulfate.
4. The differences between moisture gains in samples containing similar additives suggested that factors other than composition of fire retardants also affect moisture gain, such as the size and distribution of the additives and the characteristics of the cellulose matrix.
5. The apparent moisture gains observed during testing were dependent upon the specimen configuration. For example, sample 563-5, when tested in the low-density configuration had an unacceptable 22 percent moisture gain. However, when tested in 1000 and 2000 ml beakers, the moisture gains were an acceptable 6 and 8 percent respectively.

#### D. CORROSIVENESS

The nineteen samples were tested for corrosiveness in accordance with ASTM C739-73, section 10.7, except that thicker metal test coupons were used. The thicker coupons (0.25 inches/0.6 cm) were selected to allow more detailed evaluation of the mechanisms and rates of possible corrosion. The test coupons specified in ASTM C739 are only 0.003 inches thick and failure of test is based on visual observance of perforation of the coupon.

The coupons, tested in duplicate for each cellulosic samples, were:

1. Steel, AISI type 1018, cold rolled, 5 cm x 6.3 cm x 0.6 cm.
2. Aluminum, alloy 2024-0, (annealed) 5 cm x 5 cm x 0.6 cm.
3. Copper, type K tubing, 5 cm x 1.5 cm O.D.

As specified in the standard, the coupons were placed in contact with the cellulosic samples that had been moistened with water and held for thirty days at 120°F and 96% R.H. Because of the difficulty in expressing the corrosion results adequately in terms of a single number or term, the data were reported by corrosion type; general or uniform, pitting, and subsurface.



TABLE II  
Moisture Weight Gains in Cellulosic Insulation Samples

A. Moisture Gain (%) in Low-Density Packing Configuration

Sample Identification	Pre-Test Conditioning (50% RH)	Test Exposure (90% RH)		
		24 Hour *	8 days	15 days
525-1	2.4	38.5	76.5	43.7
525-5	1.1	9.5	18.2	19.3
527-A	1.1	5.6	7.7	6.7
527-B	1.3	5.6	7.2	6.0
527-C	-0.5	7.8	9.0	8.4
527-C1	0.1	7.3	8.4	7.9
527-D	2.2	10.9	16.4	20.4
527-E	2.2	29.0	65.9	70.0
527-F	1.1	10.0	9.7	8.5
527-G	2.2	24.1	43.2	37.4
527-H	2.6	7.0	5.5	3.8
527-I	2.5	24.8	50.7	42.5
535	-0.3	10.3	16.4	14.9
562	1.8	11.2	20.2	19.6
563-4	0.5	11.6	16.8	14.4
563-5	0.7	21.6	55.1	29.5
563-6	0.7	10.6	15.0	10.1
563-7	0.6	12.3	13.1	10.3
593	1.2	19.6	30.3	29.7

B. Moisture Gain for Different Packing Configurations

527-A, Low Density	1.1	5.6	7.7	6.7
527-A, 2000 Ml Beaker	1.4	4.0	6.9	6.9
527-A, 1000 Ml Beaker	1.5	3.5	6.4	6.5
562, Low Density	1.8	11.2	20.2	19.6
562, 2000 Ml Beaker	2.2	4.9	13.1	17.1
562, 1000 Ml Beaker	1.8	4.3	12.2	15.2
563-5, Low Density	0.7	21.6	55.1	29.5
563-5, 2000 Ml Beaker	1.1	7.6	23.5	29.2
563-5, 1000 Ml Beaker	1.1	6.0	21.1	26.4

\* Standard ASTM test, acceptance level set at less than 15% gain.

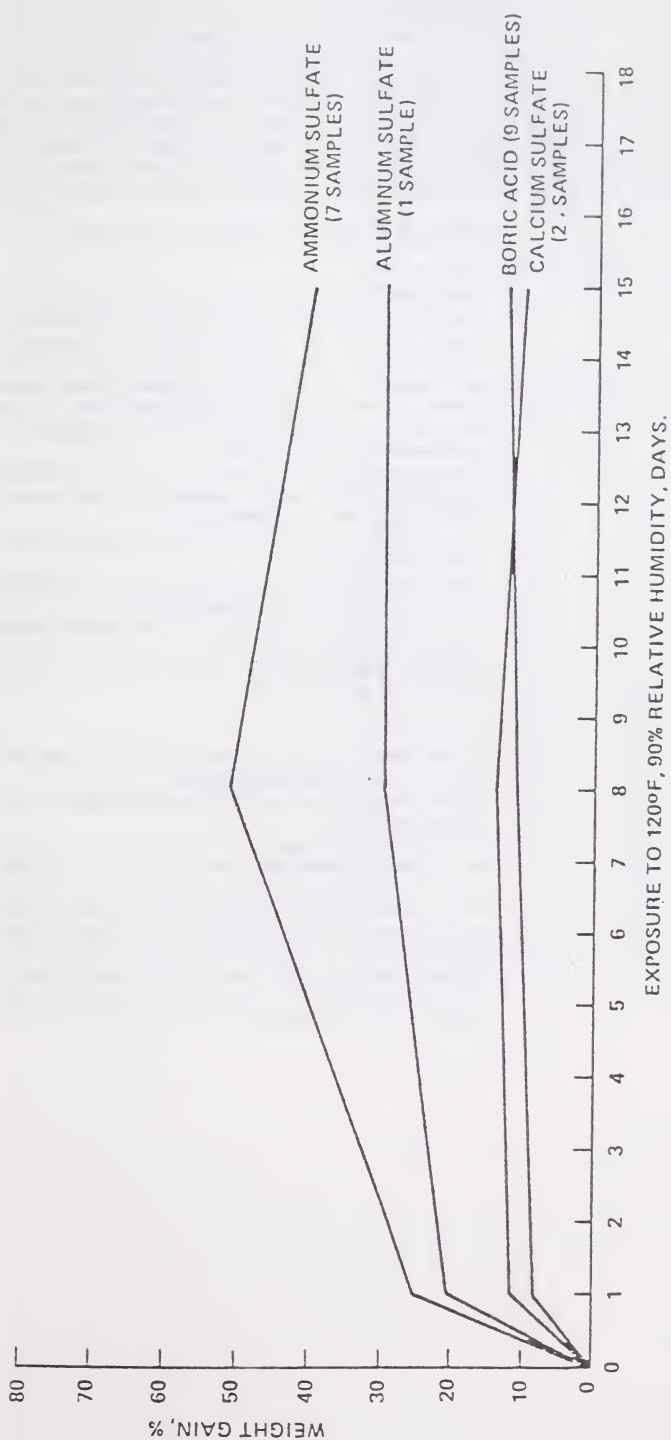


FIGURE 1. EFFECT OF FIRE RETARDANT COMPOSITION ON MOISTURE WEIGHT GAIN.

General corrosion was determined by measuring the coupon weight loss during the test, and calculating the equivalent uniform loss of thickness over all surfaces of the test coupon. Pitting corrosion was determined by microscopic measurement of the depths of individual surface pits below the final coupon surface. Subsurface corrosion was determined by metallographic analysis of cross-sections of the coupons thereby indicating both the depth and mechanism of corrosion; e.g., intergranular. Again, all measurements were made from the final coupon surface. The general corrosion data are given in Table III and Figure 2. Pitting corrosion data are given in Table IV.

Examination of the corrosion test data showed the following:

*General Corrosion:*

1. The corrosion experienced by the individual test coupons was not uniform, but rather much greater on one of the surfaces, and, in many cases variable over the surface. Apparently corrosion was greater at points of intimate physical contact between the coupon and the cellulose. Consequently, the calculated general corrosion reported in Table III and Figure 2 represents conservative corrosion values: it is roughly estimated that the corrosion areas were approximately twice those reported.
2. A wide range of corrosion rates of the test materials were observed between the cellulosic samples. Generally, the steel coupons experienced the greatest rate of corrosion.
3. There was poor correlation between corrosion rates, composition of fire retardant, and pH.
4. Based on the calculated general corrosion rates, eleven of the nineteen samples showed corrosion rates greater than allowed under ASTM C739-73 for one or more of the test coupon materials. (The corrosion rate to completely dissolve the 0.003 inch thick test coupons specified in ASTM C739-73 in the 30-day test period is equivalent to 0.45 mm per year.)

*Pitting Corrosion:*

5. The observed pit depths are conservative, since measurements were taken from the final coupon surfaces.
6. Only the aluminum test coupons showed any significant amount of pitting corrosion.
7. All nineteen cellulosic samples produced pitting in the aluminum test coupons to an extent greater than allowed in ASTM C739-73 (The ASTM standard test coupon is 0.003 inches or 0.076 mm thick.) However, the control sample, which was exposed only to the test atmosphere, also showed excessive pitting. Of the nineteen coupons tested against the cellulose samples, twelve exhibited pitting depths greater than that observed on the control coupon. The standard specifications do not require the evaluation of control coupons in the corrosion tests.

8. Essentially no correlation was observed between the pitting of aluminum, composition of fire retardant, and pH.

*Subsurface Corrosion:*

9. There was extensive subsurface corrosion in the form of intergranular attack in the aluminum test coupons. Maximum observed depths of subsurface attack were in the 0.008–0.010 inch range. Although no attempt was made to correlate depth of attack with fire retardant composition and pH, deep attack was observed in test coupons exposed to samples containing boric acid and ammonium sulfate.
10. Subsurface corrosion of the copper test coupons was limited to an observed maximum of about 0.0005 inches and was considered negligible.
11. The steel test coupons had no observable subsurface corrosion.

TABLE III  
Rates of General Corrosion of Aluminum, Copper and  
Steel Exposed to Cellulosic Insulation Samples,  
Millimeters per Year\*

Sample Identification	Aluminum	Copper	Steel
Control**	0.18	0.05	0.05
526-1	0.29	0.75	1.57
526-5	0.14	Nil	0.77
527-A	0.05	Nil	0.19
527-B	0.16	0.07	1.53
527-C	0.06	Nil	0.46
527-C1	0.29	Nil	0.38
527-D	0.25	0.03	0.36
527-E	0.10	0.78	0.33
527-F	0.07	Nil	0.43
527-G	0.11	0.47	1.57
527-H	0.06	Nil	0.15
527-I	0.39	0.30	0.98
535	0.24	0.04	0.58
562	0.26	0.20	0.16
563-4	0.06	0.10	1.12
563-5	0.20	0.36	0.38
563-6	0.14	0.03	0.87
563-7	0.11	0.03	0.34
593	0.22	0.33	2.24

\* Base on 30-day test period

\*\* Control samples exposed only to test atmosphere

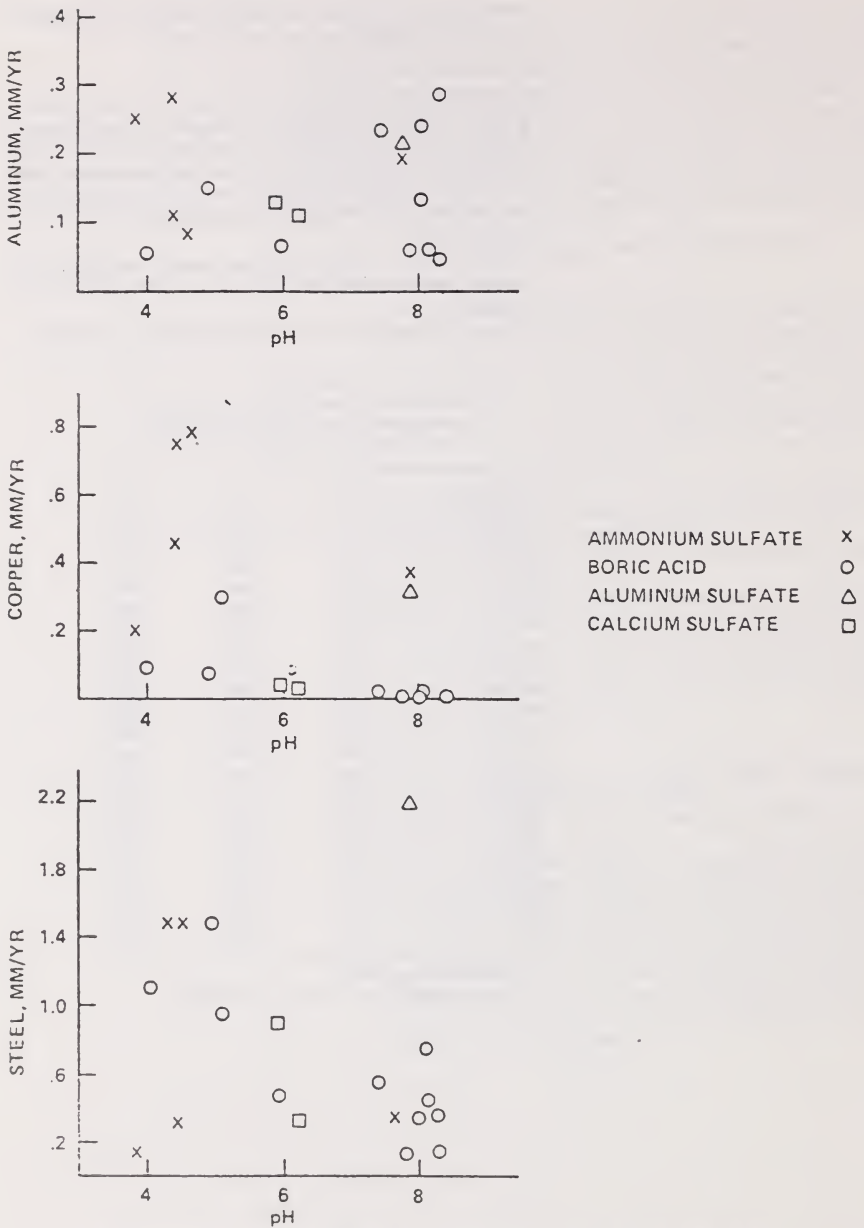


FIGURE 2. EFFECT OF COMPOSITION AND pH ON GENERAL CORROSION RATES.



TABLE IV  
Maximum Pit Depth on Aluminum Exposed to Cellulosic  
Insulation Samples for 30 Days

Sample Identification	Pit Depth M. millimeters
Control	0.33
526-1	0.25
526-5	0.66
527-A	0.15
527-B	0.15
527-C	0.33
527-C1	0.76
527-D	0.99
527-E	0.28
527-F	1.04
527-G	0.63
527-H	0.33
527-I	0.66
535	0.48
562	0.96
563-4	0.66
563-5	1.07
563-6	0.61
563-7	0.55
593	0.81

#### E. RESISTANCE TO FUNGAL GROWTH

Fungi which degrade cellulose are widespread and are found in virtually all environments. Generally, these fungi require temperatures in the 50-100°F range and a relative humidity of 60 percent or greater. It is possible that fungal growth on cellulosic insulation could cause the following undesirable conditions:

- a. provide a source of fungal spores which can penetrate the living area and cause health problems,
- b. degrade the thermal properties of the insulation by destroying the structure of the cellulose, and
- c. increase the corrosive action of the insulation material through accumulation of metabolic products.

Testing for fungal growth is not included in the ASTM, Federal or industry specifications.

The nineteen cellulosic samples were tested on a "go, no-go" basis to determine the propensity for fungal growth. The samples were tested at 86°F and 95 percent relative humidity for 28 days in accordance with military testing specification Military Standard 810B, method 508. Results of those tests showed the following:

1. Cellulosic samples containing primarily boric acid were resistant to fungal growth.

2. Cellulosic samples containing primarily ammonium sulfate supported fungal growth. Visible indications of growth were observed after 2-3 weeks exposure in sample 526-1, 527-E, 527-G, 563-5 and 562.
3. The cellulosic sample containing primarily aluminum sulfate (593) supported fungal growth; visible indications of growth were observed after 2 weeks exposure.
4. The existence of fungal growth after 28 days exposure would be difficult for the untrained or casual observer to detect because of the coloration and texture of the cellulosic matrix.

#### F. THERMAL CONDUCTIVITY AND FLAME SPREAD

Only eight of the nineteen cellulosic samples were tested for thermal conductivity and flame spread by a non-Federal organization prior to the foregoing tests performed at the Naval Laboratory. The thermal conductivity tests were reportedly performed in accordance with ASTM C518-70, Thermal Conductivity of Materials by Means of the Heat Flow Meter Method. Likewise, the flame spread tests were performed in accordance with ASTM E84-75, Test For Surface Burning Characteristics Of Building Materials.

Both of the above tests are included in the ASTM, Federal and Industry specifications. The results of the tests are given in Table V.

Examination of these data show the following:

1. For most of the samples, the thermal conductivity values obtained through independent testing were significantly higher than corresponding values reported by the manufacturers. The differences in value were greater than could be expected from differences in test densities.
2. Flame spread data reported by the manufacturers were in good agreement with those obtained through independent testing. The data indicate that both boric acid- and ammonium sulfate-based fire retardants are capable of affording the flame spread levels defined in the standard specifications.

TABLE V  
Thermal Conductivity and Flame Spread  
Values for Cellulosic Insulation Samples

## A. Thermal Conductivity

	Manufacturer's Data		Independent Data		Deviation in "K" Values, %
	Test Density pcf	"K" BTU-in Hr-ft <sup>2</sup> ·°F	Test Density pcf	"K" BTU-in Hr-ft <sup>2</sup> ·°F	
527-A	3.0	.25	2.9	.35	40
527-B	2.3	.20	2.8	.31	55
527-C	3.0	.19	2.6	.31	63
527-C1	—	—	2.4	.30	—
527-D	2.4	.27	2.7	.32	18
527-E	—	.24	2.2	.29	21
527-F	1.8	.26	2.2	.29	12
527-G	2.2	.27	2.3	.27	0

## B. Flame Spread

	Manufacturer's Data*	Independent Data**
527-A	15	10
527-B	10	20
527-C	38	15
527-C1	—	—
527-D	30	20
527-E	—	15
527-F	20	15
527-G	—	10

\* Test method not known

\*\* ASTM E84 25-foot tunnel tester

## IV. CONCLUSIONS

A survey of cellulose thermal insulation materials has provided base level property data heretofore unavailable and an assessment of the suitability of specification standards for defining the properties and quality of the material. Since the survey included samples of only nineteen commercially available products from an estimated one hundred manufacturers, the results and conclusions cannot be interpreted as pertaining to every manufacturer. But rather, the results must be reviewed in total to identify overall trends or patterns and serve as a base from which manufacturers can improve their products and consumers can better choose a product. The results also provide a basis from which organizations responsible for preparing cellulosic insulation standard specifications can evaluate the adequacy of their standards.

Specific conclusions derived from this survey were as follows:

1. A variety of fire retarding chemicals are added to cellulose in quantities ranging to about 25 percent. The chemicals are added either singularly or are combined. Types of chemical additives used include:
  - ammonium sulfate
  - "borates", e.g., boric acid and borax
  - aluminum sulfate
  - calcium sulfate
  - sodium carbonate
2. The pH of the samples, when contacted with water, ranged from 3.7 to 8.2. The standard specifications neither limit nor require reporting of pH values.
3. Some separation of fire retardant chemicals from the cellulosic matrix occurred in thirteen of the nineteen samples surveyed after handling under normal conditions. The standard specifications do not include criteria for retention of fire retardant chemicals.
4. Six of the nineteen samples exceeded the moisture absorption criteria of the standard specifications when tested in a low-density configuration (e.g., as may be found in attic installations). Excessive moisture absorption rates were generally found in samples containing ammonium sulfate and aluminum sulfate. The standard specifications do not adequately define the testing conditions for moisture absorption tests.
5. The capacity of cellulosic materials to absorb moisture is variable. Extended testing at 120°F and 90 percent relative humidity showed weight gains ranging from 5 to 76 percent. The standard specifications do not provide limits for moisture absorption over long-term exposure.
6. The cellulosic materials exhibited a wide range of corrosiveness against aluminum, copper and steel when tested in accordance with the standard specifications. Three types of corrosion were observed:
  - a. general corrosion (dissolution of the metal)
  - b. pitting corrosion, and
  - c. subsurface corrosion (intergranular)

When compared with the limits of corrosion provided in the standard specifications, eleven of the samples produced excessive general corrosion, primarily when in contact with steel. Excessive pitting and subsurface corrosion were observed on aluminum coupons when tested against most of the cellulose samples. The standard specifications do not differentiate between different types of corrosion, nor do they consider the full extent of possible corrosion. Because of the poor correlation between composition and pH of the cellulose samples and observed corrosion, composition and pH cannot be used as indicators of corrosiveness.

7. Six of the nineteen samples supported fungal growth when tested at 86°F and 95 percent relative humidity for 28 days. Samples containing boric acid were resistant to fungal growth, whereas samples containing primarily ammonium sulfate or aluminum sulfate supported fungal growth. The standard specifications do not include criteria for fungal growth resistance.
8. Thermal conductivity values for seven of the eight samples tested exceeded the values reported by the manufacturers; the range of deviations was 11–63 percent. The standard specifications allow only a 5 percent deviation.
9. Flame spread ratings obtained from the eight samples tested were in good agreement with values reported by the manufacturers. The chemicals used in the tested samples were effective in providing flame spread resistance as defined under the standard specifications.

## V. RECOMMENDATIONS

The results of this survey show the need for a better understanding of the parameters which control the performance of cellulosic insulation and the need for improved standard specifications. Therefore, the following recommendations are offered:

1. That the performance criteria of cellulosic insulation be reevaluated and, where necessary, redefined and/or new performance criteria identified. Items to be included in the reevaluation should be:
  - retentivity and stability of fire retardant additives
  - moisture absorptivity
  - resistance to fungal growth
  - corrosiveness
2. That the standard specifications be modified to insure effective specifications for product quality and performance.
3. That manufacturers of cellulosic insulation place greater emphasis on compliance with standard specifications.
4. That consumers of cellulosic insulation insist that purchased materials are in compliance with the standard specifications and, when feasible, check for such compliancy by independent testing.



## APPENDIX A—PROCEDURE FOR ANALYZING FIRE RETARDANT ADDITIVES

- (1) Check sample for organic additives by extraction with suitable solvents. Check sample for ethanol solubles in particular.
- (2) Oven dry a weighted sample at 80°C for one hour to determine moisture level "as received."
- (3) If results of (1) through (2) are negligible, proceed with water extraction.
- (4) Combine 5 grams of insulation sample with 100–200 ml distilled water in suitable container and warm on hot plate for 5 minutes. Stir occasionally.
- (5) Remove water and dissolved material from wet cellulose by vacuum filtration. Retain washed cellulose on filter paper in buchner funnel.
- (6) Set aside 100 ml of the filtrate for analysis.
- (7) Wash cellulose with three 100 ml portions of hot distilled water and one 50 ml portion of 95 percent ethanol.
- (8) Transfer cellulose to watch glass and dry one hour at 100°C.
- (9) Weigh watch glass and cellulose. Place cellulose in labeled bottle, wipe dust from watch glass and weigh.
- (10) Computer weight of dried cellulose and percent water solubles by difference.
- (11) Heat filtrate retained in step (6) at 80–90°C until water has evaporated. Remove dried solids, grind and mix to assure uniformity. Place in labeled vial.
- (12) Perform emission spectrographic and X-ray fluorescence analyses to detect elements.
- (13) Confirm compounds and elements detected in steps (11) and (12) using X-ray diffraction and differential thermal analysis.
- (14) Quantitatively determine metallic elements using atomic absorption spectrophotometry.
- (15) Quantitatively determine metallic elements by using the quantity of that element present and the molecular weight of the most likely molecular form and hydration state.
- (16) Quantitatively determine those compounds which do not contain metallic elements by subtracting known substances in those cases where all residue components are identifiable.

## APPENDIX B—PROCEDURE FOR DETERMINING pH OF CELLULOSIC SAMPLES

- (1) Allow a quantity of distilled water to equilibrate with atmospheric CO<sub>2</sub> (approximately pH 5.7).
- (2) Add 50 ml of water to one gram insulation sample and stir for approximately five minutes using an electric stirrer.
- (3) If the sample does not wet readily, add 0.1 ml of a 5 percent Trident Solution to the mixture prior to stirring. (This will not alter the final pH).
- (4) Using a Beckman Zeromatic pH meter and Combination Electrode (Beckman Part No. 39013), determine the pH of the suspension.

## APPENDIX 11

## NINETY-FIFTH CONGRESS

JOHN E. MOSS, CALIF., CHAIRMAN

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 (EX OFFICIO)

## CONGRESS OF THE UNITED STATES

## HOUSE OF REPRESENTATIVES

SUBCOMMITTEE ON OVERSIGHT AND INVESTIGATIONS  
OF THE

## COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE

WASHINGTON, D.C. 20515

Room 3323

RAYBURN HOUSE OFFICE BUILDING  
PHONE (202) 225-4441JAMES L. WELLSMAN  
OPERATIONS DIRECTORJOHN MCLEARY ATKINSON  
COUNSEL TO THE SUBCOMMITTEETASK FORCE DIRECTORS  
LOWELL DODGE—OVERSIGHT  
JOHN R. GALLAGHER—ENERGY  
ELIJAH A. SEGAL—HEALTHJ. THOMAS GREENE  
COUNSEL TO THE CHAIRMANBERNARD J. HUNTER  
MINORITY COUNSELMEMORANDUM

DATE: February 17, 1978

TO: John E. Moss  
Chairman

FROM: Energy Subcommittee Staff

SUBJECT: Manufacturers of Cellulose Insulation that  
Failed Tests Conducted by ERDA

The enclosed is submitted pursuant to your directive to determine the names of the manufacturers whose product failed the various tests conducted by ERDA and reported on in ERDA report #77-23, dated January 1977, entitled "Survey of Cellulosic Insulation Material."

In some cases it was not possible to identify the manufacturer. Those that can be identified, based on a review of ERDA files, are as follows:

"Conclusion 3. Some separation of fire retardant chemicals from the cellulosic matrix occurred in thirteen of the nineteen samples surveyed after handling under normal conditions. The standard specifications do not include criteria for retention of fire retardant chemicals."

Identifiable Samples Experiencing Separation  
of Retardant Chemicals

<u>Sample</u>	<u>Company Name and Location</u>
526-1	Construction Concepts, Inc.
562	Cellin Manufacturing, Inc. <sup>1/</sup> (Cellincraft) Lorton, Virginia

---

1 Members of the National Cellulose Insulation Manufacturers Association (NCIMA)

663-4	Regal Insulation Company (Regal) Crothersville, Indiana
593	U.S. Fiber Corporation <sup>1/</sup> (Professional Blowing Insulation) Delphos, Ohio

"Conclusion 4. Six of the nineteen samples exceeded the moisture absorption criteria of the standard specifications when tested in a low-density configuration (e.g., as may be found in attic installations). Excessive moisture absorption rates were generally found in samples containing ammonium sulfate and aluminum sulfate. The standard specifications do not adequately define the testing conditions for moisture absorption tests."

Identifiable Samples Exceed the Moisture Absorption Criteria of the Standard Specifications When Tested in a Low-Density Configuration

<u>Sample</u>	<u>Company Name and Location</u>
562	Cellin Manufacturing, Inc. <sup>1/</sup> (Cellincraft) Lorton, Virginia
563-5	U.S. Fiber Corporation <sup>1/</sup> (Attic Insulation) Delphos, Ohio

"Conclusion 6. The cellulosic materials exhibited a wide range of corrosiveness against aluminum, copper and steel when tested in accordance with the standard specifications. Three types of corrosion were observed:

- a. general corrosion (dissolution of the metal);
- b. pitting corrosion; and
- c. subsurface corrosion (intergranular).

When compared with the limits of corrosion provided in the standard specifications, eleven of the samples produced excessive general corrosion, primarily when in contact with steel.\* \* \*"

---

1 Members of the National Cellulose Insulation Manufacturers Association (NCIMA)

Identifiable Samples Showing Excessive General Corrosion

<u>Sample</u>	<u>Company Name and Location</u>
562	Cellin Manufacturing, Inc. <sup>1/</sup> (Cellincraft) Lorton, Virginia
563-5	U.S. Fiber Corporation <sup>1/</sup> (Attic Insulation) Delphos, Ohio
593	U.S. Fiber Corporation <sup>1/</sup> (Professional Blowing Insulation) Delphos, Ohio

"Conclusion 7. Six of the nineteen samples supported fungal growth when tested at 86° and 95 percent relative humidity for 28 days. \* \* \*"

Identifiable Samples Showing Fungal Growth

<u>Sample</u>	<u>Company Name and Location</u>
526-1	Construction Concepts, Inc. <sup>1/</sup>
563-5	U.S. Fiber Corporation <sup>1/</sup> (Attic Insulation) Delphos, Ohio
562	Cellin Manufacturing, Inc. <sup>1/</sup> (Cellincraft) Lorton, Virginia
593	U.S. Fiber Corporation <sup>1/</sup> (Professional Blowing Insulation) Delphos, Ohio

---

1 Members of the National Cellulose Insulation Manufacturers Association (NCIMA)

## EXHIBIT 12

The 39 manufacturers of Loose Fill Cellulose Insulation that currently subscribe to the Underwriters Laboratories (U.L.) labeling and follow up Fire Hazard Classification and Service are:

B & D Mfg. Co.  
Marshall, Texas 75670

Bertrand, Inc.  
Melvindale, Michigan 48122

Bonded Insulation Co., Inc.  
Hagaman, New York 12086

C. F. I. of Arizona  
Scottsdale, Arizona 85251

Cellin Mfg. Inc.  
Lorton, Virginia 22079

Cell-U-Fill  
Sacramento, California 95828

Cellulose Insulation Mfg. Inc.  
Midvale, Utah 94047

Electra Mfg. Corp.  
Toledo, Ohio 43615

Energy Control, Inc.  
Ossian, Indiana 46777

Energy Guard Mfg.  
Erie, Michigan 48133

Fiber Cel Corp.  
Woodland, California 95695

Fibron Corp.  
Portland, Oregon 97203

Galens Mfg. Corp.  
Rochester, New York 14609

General Recycling Corp.  
South Bend, Indiana 46680

Golden Therm, Inc.  
Milpitas, California 95035

Habitat Technology, Inc.  
Humble, Texas 77338

Incel Corp.  
Bluffton, Indiana 46714

Inland Mfg. Inc.  
Weiser, Idaho 83672

International United  
Chemical Co., Inc.  
Los Angeles, California 90003

Iowa Excell Corp.  
Pottsville, Iowa 52162

National Cellulose Corp.  
Houston, Texas 77045

National Insulation Co.  
Bay City, Michigan 48732

Nichol Co.  
West Des Moines, Iowa 50265

Northern Insulation Products  
Division of Lloyd  
Refrigeration, Inc.  
Gibbon, Minnesota 55335

Oren Corp.  
Muncie, Indiana 47302

Pace National Corp.  
Kirkland, Washington 98033

Prairie Marketing Corp.  
Lincoln, Nebraska 68529

Pyrotherm Insulation, Inc.  
Pine Bluff, Arkansas 71601

R.B.H. Transportation Co., Inc.  
El Segundo, California 90245

Specialty Insulation Inc.  
Spokane, Washington 99202

Superior Fiber Corp.  
San Lorenzo, California 94580



Therma-Coustics Mfg. Inc.  
Colton, California 92324

Thermoguard Insulation Co.  
Seattle, Washington 98134

Thermo Products Co.  
Chilton, Texas 76632

Thermtron Products, Inc.  
Fort Wayne, Indiana 46809

U. S. Fiber Corp.  
Delphos, Ohio 45833

Urethane Specialities, Inc.  
Anchorage, Alaska 99503

Western Weathercheck  
Santa Clara, California 95050

Wheeler Insulation, Inc.  
Battle Creek, Michigan 49017

## EXHIBIT

The <sup>15</sup> manufacturers of Loose Fill Cellulose Insulation that currently subscribe to the Underwriters Laboratories' (U.L.) labeling and follow up service for fire hazard classification, density, thermal resistance, moisture absorption, odor emission, corrosiveness, starch content, and flame resistance permanency are:

Amerigard, Inc.  
Fresno, California 93721

Capitol Insulation Co.  
Denver, Colorado 80204

Cel-U-Con Insulation Co.,  
Division of AHK Corp.  
South San Francisco, Calif. 94124

Diamond Insulation Mfg., Inc.  
Denver, Colorado 80223

Diversified Insulation, Inc.  
Hamel, Minnesota 55340

General Fiber Corp.  
Commerce City, Colorado 80022

John Hartin Co.  
Amarillo, Texas 79101

Lane's Quality Insulation Co.  
San Francisco, California 94124

Mono-Therm Industries, Inc.  
Kirkland, Washington 98033

Solarcell Corp.  
Englewood, Colorado 80110

Spangler Fiber Wool, Inc.  
Belleville, Kansas 66935

Sun-Tec Industries  
Aurora, Colorado 80010

Superior Products Corp.  
Boulder, Colorado 80320

Thermal Shield, Inc.  
Hesston, Kansas 67062

Wholesale West  
Idaho Falls, Idaho 83401

## APPENDIX 13

## MANUFACTURERS' NOT USING LABELS IN 1977

<u>FACTORY NO.</u>	<u>MANUFACTURERS' NAME</u>	<u>LOCATION</u>	<u>SERVICE STARTED</u>
291	B & D Mfg. Co.	Marshall, TX	5/09/75
301	Bertrand Insulation	Melvindale, MI	6/03/77
311	Bonded Insulation	Hagamen, NY	2/28/73
322	C.F.I. of Arizona	Phoenix, AZ	7/11/77
341	Energy Control, Inc.	Assian, IN	12/10/76
351	Energy Guard	Erie, MI	7/18/77
362	Galens Mfg. Corp.	Clyde, NY	3/04/77
371	General Fiber	Commerce City, CO	10/06/76
381	Inland Mfg., Inc.	Weiser, ID	11/29/77
392	International United Chemical Corp.	S. El Monte, CA	10/04/77
401	Iowa Excel Corp.	Pottsville, IA	12/24/75
411	John Hartin Co.	Amarillo, TX	8/02/77
422	National Insulation	Cheboygan, MI	5/04/77
431	Prairie Marketing	Lincoln, NE	11/22/77
441	Pyrotherm Insulation	Pine Bluff, AR	7/21/77
451	R.B.H. Transportation	El Segundo, CA	12/03/75
471	Silvertip Cellulose	Caldwell, ID	12/01/77
481	Spangler Fiber Wool	Belleville, KS	12/27/76
491	Specialty Insulation	Spokane, WA	11/30/77
242	Thermo-Products	Chilton, TX	10/05/77
511	Thermo-Kool	Dothan, AL	11/29/76
521	Thermtron	Ft. Wayne, IN	10/06/75
532	Urethane Specialties	Anchorage, AK	8/29/77
541	Wheeler Insulation	Battle Creek, MI	12/07/77
552	Wholesale West	Idaho Falls, ID	10/27/77
561	Collin Mfg.	Lorton, VA	2/04/76
571	General Recycling	South Bend, IN	4/25/77

## APPENDIX 14



State of Colorado

Metropolitan Denver District Attorneys'  
CONSUMER OFFICE

October 14, 1976

655 South Broad  
Merchants Park Ct  
Denver, Colorado 80  
(303) 777-1

Noan L. Brown, Chairman  
District Attorney  
Jefferson County

Robert Gallagher, Jr.  
District Attorney  
Arapahoe County

Alex Hunter  
District Attorney  
Boulder County

Floyd Marks  
District Attorney  
Adams County

Dale Tooley  
District Attorney  
Denver County

Executive Director  
Felicia Muffie

To The Commissioners  
United States Consumer Product  
Safety Commission  
5400 Westbard Avenue  
Washington, D.C. 20207

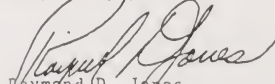
Dear Sirs:

Enclosed please find an Original Petition To The  
United States Consumer Product Safety Commission  
and four (4) copies. Each set includes the  
Petition, an Index to the Appendix and nine (9)  
appendices.

We have put a great deal of work and scholarship  
into our Petition and entreat you to give it the  
fullest possible consideration.

If there are questions please do not hesitate to  
contact us.

Very truly yours,

  
Raymond D. Jones  
Chief Counsel

RDJ/cm  
Enclosures

400 113475

36. 656 07 100

100 113475



# State of Colorado

## Metropolitan Denver District Attorneys' CONSUMER OFFICE

Nolan L. Brown, Chairman  
District Attorney  
Jefferson County

Robert Gallagher, Jr.  
District Attorney  
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Alisa Hunter  
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655 South Broadway  
Merchants Park Center  
Denver, Colorado 80209  
(303) 777 3072

October 3, 1976

To The Commissioners  
United States Consumer Product  
Safety Commission  
5400 Westbard Avenue  
Washington, D.C. 20207

Dear Sirs:

IN RE:

HAZARDS IN HOME  
INSULATION

PETITION TO THE  
UNITED STATES CONSUMER  
PRODUCT SAFETY COMMISSION

COMES NOW the Metropolitan Denver District Attorneys' Consumer Office by and through it's counsel and others, all hereinafter referred to jointly and severally as Petitioners, and petition the United States Consumer Product Safety Commission ("Commission") to commence a proceeding for the issuance of a consumer product safety rule with regard to the manufacture and installation of home insulation.

AS GROUNDS herefore, Petitioners set forth the following facts and appendices:

### I. JURISDICTION

1. This petition is filed pursuant to section 10, Commission Responsibility - Petition For Consumer Product Safety Rule, of the Consumer Product Safety Act of 1972, as amended; Pub. L. 92-573; 86 Stat. 1207 et seq.; 15 U.S.C. 2051 et seq., hereinafter referred to as the Act.

### II. PURPOSES

2. Commensurate with Findings and Purposes of the Act, Petitioners have observed that the public has for too long been subjected to unreasonable risks of injury, sickness and death caused by faulty and careless manufacture of home insulation and by incompetent and negligent installation of such insulation. The increasing cost of home heating fuels, as well as proposed

legislation currently being considered by Congress which would provide a tax credit for home owners who improve the insulation in their homes make it likely that there will be a dramatic increase in demand for home insulation products which increase shall magnify the problems observed.

3. Uniform safety standards and testing methods do not exist among the various levels of government and conflicts in or the absence of Federal, State and local laws and ordinances regarding home insulation contribute to the risks of injury, sickness and death which consumers face.

4. Research and investigation are needed to examine potential and real cases of injury, sickness and death, and to prevent the same, related to home insulation.

### III. INTRODUCTION

5. Presently, at least three types of insulation materials are available for use in residential structures which Petitioners submit present unreasonable risks of injury, sickness and death to consumers, to wit: fibrous glass (fiber glass, mineral wool or rock wool); cellulosic fiber; and plastic foam/resin (polyurethane, polystyrene or urea formaldehyde).  
See App. I.

6. The above-recited materials and the types of dwellings into which they are designed to be installed are covered by the definition of "consumer product" set forth in the Act, section 3(a)(1) and do not fall within any exclusion thereto. Act, sec. 3(a)(1)(A)-(1). Furthermore, sections 30(d) and 31 of the Act do not prohibit the Commission from commencing proceedings pursuant to this Petition.

### IV. DESCRIPTION OF RISKS AND HAZARDS PRESENTED

#### A. HEALTH HAZARDS [See App. II.] (1) Cellulose

7. Health hazards have been observed with regard to misleading advertising and variable testing for thermal resistance which make it unlikely that consumers can possibly know to what extent their homes are insulated. This condition leads to higher than anticipated fuel bills and to difficulty in regulating home temperature, resulting in discomfort and sickness, difficulties of vermin resistance and inhalation of dust problems.  
See App. II; III.



## (2) Fibrous Glass

8. Studies have shown (at least by analogy) that there is a distinct possibility that fibrous glass, which is made up of compacted, tiny particles of fiber glass or mineral or rock wool, may cause cancer in the respiratory and the gastrointestinal tracts, due to inhalation and ingestion of particles during installation, especially careless or improper installation. Over time these same problems may arise by the spreading of particles through the processes of settling and sifting of the insulation while it is in place, or being drawn into air intakes of heating and cooling systems vented to the attic, especially in cases of poorly installed materials. Furthermore, these problems result in discomfort and sickness due to unregulated temperatures. See App. IV.

## (3) Plastic Foam/Resin

9. Plastic foam insulations present the lingering health hazard of noxious odors which cause great discomfort and sickness if improperly installed. Furthermore, these insulations are susceptible to decomposition or improper curing resulting from improper formulation during installation. The resulting difficulty in regulating home temperature causes discomfort and sickness. See App. V.

## B. FIRE AND OTHER HAZARDS

## (1) Cellulose

10. A discouraging number of fire and other hazards have been observed with respect to cellulosic insulations. These hazards and some of their causes include: wide fluctuations in fire retardancy due to poor quality control in manufacturing; the danger of incompetence in the manufacturing process typified by the lack of knowledge of proper levels of fire retardant necessary for proper protection; the unknown nature of the permanency of certain fire retardants utilized and the extent to which sublimations of retardants occurs as the insulation ages after installation; the serious problem of failure to add any or proper amounts of fire retardants either at the manufacturing or installation stages, together with the absence of on-site testing; the serious variance of flame spread requirements among political subdivisions and lack of uniform test methods which result in unefficable flame spread readings; and improper installation of cellulose insulation, for instance, on or near electrical wiring, recessed lighting

fixtures, attic furnaces, heating ducts and other heat bearing or producing elements, and lack of regulation by the industry or by government of installation. See App. VI.

#### (2) Fibrous Glass

11. The use of fibrous glass which is not flammable under normal residential circumstances has been thought to reduce the hazards of fire. However, the risks of fire and resultant smoke inhalation and damage are enhanced by the following wrongful practices in the manufacture and installation of fibrous glass: use of flammable backing or vapor barrier materials which have not been included in flammability test procedures; possible collection over the duration of use of the insulation of atmospheric contaminants such as dust, oil and grease on the fibers, and lack of testing requirements or procedures for determining the affects on these materials of such contaminants. Additionally, in the manufacturing of fibrous glass, flammable oils and resins are introduced to reduce dust and to solidify insulation materials. In the description and testing of fibrous glass, no procedure exists to determine the potential hazards of these organic materials. See App. IV(6),(7); VI(1),(3),(6).

#### (3) Plastic Foan/Resin

12. With the use of foam insulations there are increased flammability and toxicity factors resulting from frequently improper curing or mixing at the time of installation; improper manufacture of components of the insulation materials. See App. V(1),(2),(8).

### V. PROBLEMS IN THE HOME INSULATION INDUSTRY CREATING A SUBSTANTIAL RISK OF INJURY TO THE PUBLIC

13. For approximately twelve months Petitioners have been investigating the manufacture and installation of home insulation materials (along with related consumer problems of advertising, sale and follow-up to installation). The investigation has revealed serious problems in the manufacture and installation of insulation, entry into the industry and the competence or expertise of those in the insulation industry. Yearly numerous cases of sickness, injury and death are recorded which can be tied directly or indirectly to the effects of improperly manufactured or installed home insulation. Numerous fires have resulted directly or indirectly from those causes with resultant injuries, smoke inhalation and smoke and water damage

assumed to be high. See App. VI; IX; I(1)

14. Except for the assumed concern of manufacturers, there is little if any regulation of quality control or quality of raw materials or product components.

15. A favorite practice of the industry is to cut costs to maximize profits which results in shoddy, and therefore dangerous, insulation products.

16. Some basic codes, laws and regulations apply across the United States with respect to manufacture and installation of insulation materials but the question arises as to their effectiveness, the interest and concern for enforcement by either private industry or public agencies, and the knowledge and concern of private industry for the promulgation of regulations which would decrease health hazards. See App. VIII.

17. With respect to installation few regulations govern quality control of materials formulated on the installation site, and often installation of improperly manufactured materials is not monitored or if monitored not stopped. Quality control is necessary to control the proper blending of ingredients resulting in proper curing and density of installed materials.

18. Often, installation mistakes result in fires (or seriously low flame retardant and thermal resistance), see App. VI, vermin (by providing habitation with little or no vermin resistant materials added), and over-all expensive but less than effective thermal resistance with little or no utility-bill savings and certainly not the savings frequently misrepresented to the public as being possible or probable. See App. VI.

19. Testing of component materials and insulation products is difficult and complex, and is necessary during all phases of the life of the product, i.e., the manufacturing process, installation phase, and to measure the on-going efficiency of the product. See App. III(11), (12), (13); VII.

20. Actual tests and standards for testing are diverse, and laboratories for testing are few and expensive to use. Also, access to such laboratories is severely limited to a few privileged persons. See App. III(11), (12), (13); VII.

21. Who should properly monitor the manufacture and installation of insulation must be decided and stated clearly to the consuming public.

22. Proper sanctions whether administrative, civil or criminal must be developed and enforced.

VI. PROPOSAL FOR CONSUMER PRODUCT  
SAFETY RULE REGARDING HOME INSULATION

23. Petitioners propose that the Commission promulgate a Rule or Regulation respecting the manufacture and installation of all forms of home insulation.

24. Pursuant to Act, sec 10(b)(2), Petitioners recommend that the following matters of substance be made part of the Rule or Regulation promulgated by the Commission, to wit:

a) A consumer product safety standard should be established for the manufacture of the three categories of home insulation, which standard should specify at least required levels of heat resistance, fire retardancy, vermin resistance, compactness or thickness, quality of raw materials used and/or components, limited uses if any, range of thermal efficiency, toxicity, coverage area, advertising guidelines and other factors affecting manufacture and sale of home insulation. See App.VIII (8),(9),(10);

b) A certificate should be issued to be affixed to every bag or package of insulation which shall certify that the insulation conforms to the consumer product safety standards for insulation. See App. VIII(4),(5),(6),(9);

c) A reasonable testing program should be developed for all insulation which shall be uniform (in its procedures and mechanisms) throughout the United States and which shall test for compliance with the safety standards set for by the Commission. See App. VII(2),(3); VIII(1),(2),(3),(7);

d) Manufacturers should be required to label insulation products in such a way that consumers may easily identify the date and place of manufacture and the name of the manufacturer, and which sets forth applicable safety standards and which verifies that the insulation meets such standards;

e) Employees or agents of the Commission should be authorized to enter the premises of any manufacturer of insulation to inspect those premises including offices, plants, factories, warehouses and storage places for compliance or lack of compliance with the Rules and Regulations of the Commission, and to

inspect the records, books and other documents of such manufacturer;

f) Guidelines should be established for the proper installation of each category of insulation, including standards for mixing components where insulation is composed on the installation site, delineations as to where the products cannot be used, special requirements for certain geographical areas, special requirements and caveats for installation (such as prohibitions against covering light fixtures, attic furnaces and other heat bearing elements which may be present);

g) Knowing and willful violations of the safety standards or of the Rules and Regulations respecting insulation should be sanctioned by fines and/or imprisonment;

h) Citizens or the Commission (and the Department of Justice) should be entitled to restrain violations of the safety standards or of the Rules and Regulations respecting insulation through the United States District Courts, and should be entitled to serve process on violators in whatever district or jurisdiction such violator may be found, regardless of the forum in which the injunction may be brought, and should be entitled to seize products which are violations of the standards and Rules and Regulations respecting insulation;

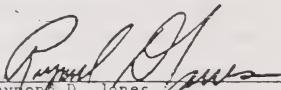
i) Any person injured by reason of a violation of a standard or Rule and Regulation respecting insulation should be entitled to sue the violator and should be entitled to recover damages sustained, and such remedy should be in addition to any other remedies available under the common law or statute;

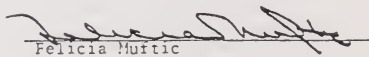
j) The Commission should rigidly and rigorously enforce the safety standards and Rules and Regulations respecting insulation

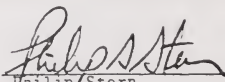
WHEREFORE, Petitioners pray the Commission grant their petition and conduct such public hearings or investigations as the Commission may deem appropriate and promulgate consumer product safety standards and Rules and Regulations respecting the manufacture and installation of home insulation.


RESPECTFULLY SUBMITTED,

The Metropolitan Denver District  
Attorneys' Consumer Office

  
\_\_\_\_\_  
Raymond D. Jones  
Chief Counsel

  
\_\_\_\_\_  
Felicia Murtic  
Executive Director

  
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Attorneys' Consumer Office  
Investigator for Environmental  
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Boulder County District Attorney's  
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3. Home Insulation Checklist, National Mineral Wool Insulation Association, Summit, N.J., publication the mineral wool industry.

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1. Insulation Manual prepared by NAIIB Research Foundation, Inc., Rockville, Md.
2. Application Manual, A Guide to Proper Installation, The Incel Corp., Bluffton, Ind.
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4. How Atmospheric Conditions affect your Health by Michel Gauquelin, Steij and Day, NY.
5. Literature depicting relationship between comfort and health, Premium Brand Rock Wool, Pueblo, Colorado.

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1. QA Cellulosic Fiber Insulation, National Cellulose Insulation Manufacturers Association, Chicago, Ill.
2. "Fire Prevention", Cellulose Insulation from Aurora Firefighter, Aurora, Colorado, 1975.
3. Investigation report by Pete Gurma, Investigator, Boulder District Attorney's Office concerning intentional decreasing fire retardant agents.
4. Denver, Colorado Fire Field Incident Report-cause cellulose fiber insulation.
5. Part of transcribed talk by Dave King to the Fire Marshall's of Colorado, April 28, 1976, Denver, Colorado,
6. Text of KMGH-TV Channel 7 Evening News presentation on Cellulose insulation problems, February 23, 1976, Denver, Colo.
7. Text of KMGH-TV Channel 7 News concerning insulation, March 10, 1976.
8. Letter from U.S. Borax Research to Phil Stern, Boulder D.A.'s Office, concerning permanency of fire retardants, January 14, 1976.
9. Dangerous Properties of Industrial Materials, N. Irving Sax, 3rd Edition, Van Nostrand Reinhold Co., 1968. Boric Acid and Boron compounds.
10. Letter from Allied Chemical Corp. to Arvin Weiss, Capitol Insulation Co., Denver, Colorado concerning properties of alum used for fire retardancy, January 4, 1974.

11. Advertisement, Superior Products Corp., Superior, Colorado illustrating possible misrepresentations about density (lack of concise standard).
12. Advertisement, Capitol Insulation Co., Denver, Colo. illustrating confusion in "R" values (difficulties in test methods and labs).
13. Advertisement, Mello Company, Richmond, Calif. selling Moncrief Formula II illustrating confusion in "R" values and test methods.
14. Federal Trade Commission consent decree in the Matter of National Cellulose Insulation Manufacturers Assoc., Inc., Electra Manufacturing Corp., Hagan Mfg. Company, Oren Corp., and Pal-O-Pak Insulation Company, Docket #C-594, Sept. 20, 1963, Washington, D.C.

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#### FIBROUS GLASS INSULATION

1. Occupational Exposure to Fibrous Glass, Proceedings of a Symposium, University of Maryland, June 26-27, 1976, sponsored by the NIOSH U.S. Dept. of Health, Education and Welfare, April, 1976.
2. Pneumonconiosis, Proceedings of the International Conference, Johannesburg, 1969. Oxford University Press, 1970. "Inhalable Fibrous Material".
3. Preliminary Industrial Hygiene Survey, Rockwool Industries, Pueblo, Colo. and Belton, Texas, HEW, Cincinnati, Ohio, Sept. 18-19, 1974.
4. Insulation Hygiene Progress Reports, Vol. 7 No 2, Summer 1975. Mount Sinai School of Medicine, NY. Higher use of small diameter fibers.
5. Dangerous Properties of Industrial Materials, N. Irving Sax, 3rd Edition, Van Nostrand Reinhold Co., 1968. Fiberglass.
6. The New Fibers, Joseph V. Sherman, D: Van Nostrand Co., NY, 1946: Article talks about combustibility of binders.
7. Insulation, Fiberglass, Manufacturing Segment of the Glass Manufacturing, Point Source Category, U.S. Environmental Protection Agency, EPA-440/1-74-001-b, January, 1974. Use of binders and lubricants in the manufacture of fibrous glass insulation.
8. Literature depicting incombustibility, permanency and vermin resistance not mentioning organic binders. National Mineral Wool Insulation Assoc., September, 1970.
9. Literature depicting the installation of fibrous insulation as being safe and without health effects (no face masks or glasses are worn nor does the woman appear to wear gloves. Johns-Manville, Denver, Colo.
10. Federal Trade Commission, "Maker of Home Insulation Cited in FTC Consent Order; Public Comment Invited", May 25, 1976.

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#### PLASTIC FOAM/RESIN INSULATION

1. Literature on urethane foam from United Foam Corp., Compton, Calif. Illustrating confusion in insulation value and flammability. Reference is made to irritating nature of isocyanate components.
2. Literature on urethane and combustibility from the Urethane Foam Contractors Association, Dayton, Ohio.

3. Insulation Hygiene Progress Reports, Vol 5 No. 4, Winter 1973. Mount Sinai School of Medicine, NY. Risks Present in Spraying Polyurethanes.
4. OSHA Rules and Regulations, Federal Register, Vol 39, No. 125, June 27, 1974. Isocyanate compounds.
5. Literature on urea-formaldehyde foam, Rapco-Foam.
6. Working with Formaldehyde, U.S. Dept. of Health, Education, and Welfare, HSM 72-10273, 1973.
7. OSHA Rules and Regulations, Federal Register, Vol. 39, No. 125, June 27, 1974. Formaldehyde.
8. FTC News, Sept. 8, 1976, "FTC orders cite marketers of UREA Formaldehyde Foam Insulation; Public Comment Invited".

#### APPENDIX VI NEWSPAPER REPORTS OF INSULATION PROBLEM

1. "Beware of Home Insulation Fraud", by Barry Koltnow, Boulder Daily Camera, Boulder, Colorado, Nov. 1, 1975.
2. "Pager Insulation Poses Threat of Fire", by Jeff Gutsell, The Sunday Chronicle, Muskegon, Michigan, Nov. 2, 1975.
3. "Insulating Profitable", by Neil Watson, Rocky Mountain Journal, Denver, Colorado, Nov. 5, 1976.
4. "Cellulose Insulation Checks Spark City Dispute", Rocky Mountain News, by Richard J. Schneider, Denver, Colorado, Feb. 25, 1976.
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- 7b "D.A.s to seek standards on home insulation", Rocky Mtn News, Denver, Colorado, May 2, 1976.

#### APPENDIX VII TEST METHODS AND PROCEDURES

1. "Eight Physical Characteristics of Cellulosic Insulation", from a talk by Nile Bucher at the annual meeting of NCIMA, Scottsdale, Arizona, April 20, 1976.
2. Test Method for Fire Hazard Classification of Building Materials, Underwriters Laboratory, UL 723, April 14, 1970.
3. Underwriters Laboratories Inc. Supplemental Test Program for Classified Loose Fill Materials, Nov. 14, 1975. (ASTM C-739 supplemental coverage).
4. Federal Specification HH-I-515C, Insulating Thermal, Cellulosic or Wood Fiber
5. Federal Specification HH-I-521D, Insulation Blankets, Thermal.
6. Federal Specification HH-I-1030, Insulation Thermal
7. ASTM C739-73. Standard Specification of Cellulosic Loose-Fill Thermal Insulation.
8. ASTM C 168-67. Standard Definitions of Terms Relating to Thermal Insulating Materials.

APPENDIX VIII

## RULES AND REGULATIONS/CONTROL &amp; CERTIFICATION

1. Letter from David Davia, Public Service of Colorado, to Joe Antonio, City-County of Denver Building Dept. concerning need for U.L. testing of cellulose materials of Class I type. July 9, 1976.
2. Public Service of Colorado specifications for insulation installation. July 1, 1976.
3. City-County of Denver Building Dept. specifications for the manufacture and installation of cellulose insulation, March 18, 1976.
4. Examples of insulation installation guarantee or certification, Diversified Insulation, Inc., Hammel, Minn.
- 5-6. Examples of insulation installation guarantee or certification, Rockwool Industries, Denver, Colo.
7. National Cellulose Insulation Manufacturers Assoc. Standard Specification for Cellulosic Fiber (Wood Base) Loose Fill Thermal Insulation, N-101-73.
8. National Cellulose Insulation Manufacturers Assoc. Standard Recommended Practice for the Application of Cellulosic Loose Fill Insulation, N-301-75, Sept. 24, 1976.
9. Example of Cellulose Labeling calling attention to flame spread rating and corrosion, Diversified Insulation, Hammel, Minn.
10. Examples of proper warnings in literature, Rockwool Ind., Denver, Colorado
  - a. Use of Face mask in diagrams and illustrations.
  - b. Warning as to "know-how" in installation.
  - c. Fire precautions due to vapor barrier flammability
  - d. Clothing and tool recommendations (we recommend that "and if desired" be deleted from the noted paragraph).

APPENDIX IX

## INSTALLATION PROBLEMS

1. Public Service of Colorado, Boulder Division, Inter-dept. Memo, damage to ceiling by improper installation, July 14, 1976

## APPENDIX 15

March 3, 1978

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## Proposed California Energy Commission Insulation Quality Standard

## CELLULOSE FIBER, LOOSE FILL, THERMAL INSULATION

All loose fill cellulosic fiber insulation sold, or installed within the State shall comply with the following minimum standards:

## DEFINITIONS:

1. "Approved Listing Agency" means any agency approved by the State Energy Commission which is in the business of listing and which makes available at least an annual published report of such listing in which specific information is included that the product has been tested to approved standards and found to comply.
  2. "Approved Testing Agency" means any agency which is determined by rule and regulations of the Commission to have adequate personnel and expertise to carry out the testing of such systems.
1. The "Standard Specification for Cellulosic Fiber (Wood Base) Loose Fill Thermal Insulation" (C-739) contained in the latest edition of American Society for Testing and Materials (ASTM), and applicable documents referenced therein;
  2. Acceptable limits on the ASTM C-739 test shall be:
    - a. Flame spread = 25 or less;
    - b. Fuel contributed = 40 or less; and
    - c. Smoke generation = 40 or less.
  3. The following changes to the ASTM C-739 test shall be:
    - a. Density - The product shall be tested using settled density according to the Test Description Number 1 and the settled density shall not be more than 3.0 pounds per cubic foot. All tests will be conducted using the settled density test results.
    - b. Corrosiveness - The product shall be tested according to the Test Description Number 2.
    - c. Critical Radiant Flux - A test for critical radiant flux shall be performed according to Test Description Number 3 as an informational test only.

Six months after the final date of compliance, the State Energy Commission shall either accept Test Description Number 3 as an additional test, delete the test or continue the test as an informational test only for additional six month study periods. The State Energy Commission shall establish the critical radiant flux level when it accepts the test.

    - d. Smoldering Combustion - A test for smoldering combustion shall be performed according to Test Description Number 4 as an additional test. When tested in accordance with Test Description Number 4,



the insulation shall meet the following requirements:

1. Weight loss less than 15 percent of critical weight.
  2. No charring within 4 cm of the sides of the specimen holder.
  3. No evidence of flaming combustion.
- e. Fungi Resistance - The loose fill insulation shall be tested for fungi resistance in accordance with MIL-STD-810, method 508. After the test exposure the test samples shall be examined at 40X magnification for evidence of fungal growth. The material shall show no evidence of fungal growth.
  - f. Odor Emission - A test for odor emission shall be performed according to Test Description Number 5. This test will replace the odor emission test described in paragraph 10.6 of ASTM C-739. A detectable odor of objectionable nature shall be cause for rejection of the insulation material and observed by two or more of the panel members.
  - g. Moisture absorption - Determination of the moisture absorption shall be in accordance with paragraph 10.5 of ASTM C-739, except the test specimen shall fill a non-permeable container 9"x9"x5" deep at the maximum settled density determined in Test Description Number 1.
  - h. Thermal resistance - Determination of the thermal resistance shall be in accordance with ASTM C-177, C-236, or C-518. The mean temperature during testing shall be 75°F (23.9°C). The thermal resistance shall be determined at the highest settled density as measured in Test Description Number 1.

The average thermal resistance R, shall be taken as the numerical average of three tests at the specified density and thickness, with evaluation performed and results reported at a 75°F (23.9°C) mean temperature.

4. Materials and Manufacture - The basic material shall consist of virgin or recycled wood-based cellulosic fiber and may be made from related paper or paperboard stock, excluding contaminated materials and extraneous foreign materials such as metals and glass which may reasonably be expected to be retained in the finished product. Suitable chemicals may be introduced to improve flame resistance processing, and handling characteristics.

The materials used must be capable of proper adhesion to the additive chemicals.

5. Approved Testing Agency - All required tests shall be performed by approved testing agencies.
6. Test Results - The test data from all required tests must be made available upon request.
7. Manufacturers of loose fill cellulosic fiber insulation shall maintain a testing and follow-up service contract with a State Energy Commission approved listing agency qualified to administer ASTM C-739 tests and the additional tests required in Section 3.
8. Requirements and duties for an Approved Listing Agency. An approved listing agency shall meet the following requirements of the State Energy



Commission when applicable:

- a. Provide a chart setting forth its organizational structure.
- b. Provide documented evidence showing the agency is in the business of testing and/or listing of materials and systems similar to those defined herein.
- c. Provide a notarized statement certifying that the agency has no proprietary interest or management ties with the manufacturer or any subsidiary of such manufacturer.
- d. Provide a detailed outline of how the in-plant inspections will be performed.
- (e) Provide at least four random in-plant unannounced inspections each month for each manufacturing plant producing the listed product.
- f. Provide an explanation of how discrepancies noted will be recorded, marked and how corrections will be obtained.
- (g) Provide a monthly written report to the State Energy Commission describing the quality control status of each manufacturing plant producing the listed product, noting any discrepancies found and how they have been corrected.
- (h) Provide an analysis to the State Energy Commission of the product chemical composition of representative samples selected at random by the approved listing agency inspector. This analysis procedure must be approved by the State Energy Commission.
- i. Provide details of how reports are to be made to the State Energy Commission together with samples of forms to be used.
- j. Select an adequate amount of sample material necessary to accomplish the testing for certification at one time.
- k. Advise the State Energy Commission within 15 days of any change in address or location.
- l. Keep up-to-date information and requirements set forth in this section.

9. Disapproval of Listed Insulation Material - An insulation shall not be accepted by the State Energy Commission when it determines that such insulation, even though listed by an approved testing agency, are not adequate for the protection to health, safety and the general welfare.

10. The State Energy Commission must approve the quality control program of a manufacturer and may at any time require additional quality control equipment and facilities.

Necessary equipment and facilities required of the manufacturer:

- a. An automatic control which will shut off the material conveying system whenever the fire retardant flow falls below acceptable levels and a means of easily testing the function of the control by an inspector.
- b. A separate room for quality control testing.
- c. A records system for recording the results of regular periodic tests and a means of locating and removing newly manufactured insulation which fails the in-plant testing procedure.

11. Product Facilities Inspection - The State of California may have an ongoing program of manufacturing plant inspections and these inspections may occur at any time. The State of California may obtain material samples from any source for independent testing to confirm results of submitted test data.



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12. Product Liability - The manufacturer must have \$1,000,000 in product liability insurance or bonding and present written evidence of such upon request.
13. Insulation bags or containers shall display at least the printed following information:
- Manufacturer's name and address;
  - Plant identity code and date of manufacture;
  - Type of insulaton, pouring or pneumatic;
  - Minimum weight of insulation per bag;
  - Manufacturer's recommendations for installation including minimum thickness, maximum coverage, and settled density (weight per square foot) to provide levels of thermal resistance (R) shown, which shall include the following table:

TABLE I. Thermal Resistance

R value at 75° Mean Temp.	Minimum Thickness	Maximum Net Coverage	Settled Density	
To obtain an Insulation Resistance (R) of:	Installed insulation should not be less than:	Maximum sq. ft. coverage per bag	Bags per 1000 sq.ft. (gross)	The weight per sq.ft. of installed insulation should not be less than:
R-40	... in. thick	... sq. feet	... bags/MSF	... lbs./sq. feet
R-32	... in. thick	... sq. feet	... bags/MSF	... lbs./sq. feet
R-24	... in. thick	... sq. feet	... bags/MSF	... lbs./sq. feet
R-19	... in. thick	... sq. feet	... bags/MSF	... lbs./sq. feet
R-13	... in. thick	... sq. feet	... bags/MSF	... lbs./sq. feet

f. Precautions to follow for installation including National Electrical Code section 410-66.

14. After this product has met the certification requirements of the State Energy Commission, it must display this seal of approval in a prominent position on the label.

